INCIDENT DETECTION BY PROBE DATA

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ABSTRACT
A fundamental study has been conducted with regard to the possibility of realizing information provision service on near misses. This would monitor hazardous phenomena broadly from linear/planar perspective, utilizing probe information showing vehicle behavior, collected through on-board devices rather than sensors placed by the roadside. Specifically, this report presents experimental results on the data analysis of vehicles behavior during sudden deceleration, abrupt steering and lane changing, which are considered to be phenomena indicating hazardous vehicle behavior.

KEYWORDS
AHS, Safety, Probe Data, UP-LINK, DSRC, Detection of Vehicle Behavior, Information Provision Service On Near Misses

INTRODUCTION
The authors have demonstrated that providing information on hazardous phenomena, detected via sensors set up at the roadside, to drivers and road administrators is an effective means of assisting safe driving [1][2]. However, while roadside sensors are capable of detecting hazardous phenomena with a high degree of accuracy, limited installation to locations where accidents frequently occur or where traffic is chronically congested are compelled due to cost constraints. Thus a feasible, inexpensive system for the implementation of broad-range monitoring is anticipated for the understanding of vehicle behavior using probe information [3].

Potentially hazardous phenomena can be presented to drivers and road administrators in the form of information on near misses and assist them to avoid accidents. Further, position, time, direction, speed, longitudinal and lateral acceleration, and yaw rate are considered to be the probe data items necessary for the analysis of vehicle behavior.
Figure 1 shows a schematic diagram of the advanced cruise-assist highway systems (AHS) service utilizing probe information. Detection of unusual behavior (sudden deceleration, abrupt steering and lane changing) from multiple vehicles at the same location enables one to anticipate that a hazardous phenomenon has arisen involving avoidance of a vehicle accident or a fallen object. Data on vehicle behavior from global positioning system (GPS), acceleration sensors and gyro-sensors utilized in car navigation is stored by an on-board device, and is then up-linked to a road management center via dedicated short range communication (DSRC) roadside units. At the road management center, information on near misses detected via statistical processing, can be used to locate hazardous points on a map, so that a map of hazardous driving locations can be provided. Information on upcoming road conditions that should be heeded can be also provided to vehicles via DSRC roadside units in real time.

FUNDAMENTAL STUDY
OBJECT

Sudden deceleration, abrupt steering and lane changing have been used as vehicle behavior data for the detection of hazardous phenomena. The purpose of this experiment is to confirm the possibility of detecting this type of vehicle behavior from probe information as a fundamental study for the implementation of AHS services such as the creation of near miss maps.

TEST TRACK STUDY

The experiment was conducted in February 2006 utilizing a passenger vehicle equipped with an on-board unit capable of acquiring probe information. The test track of the National Institute for Land and Infrastructure Management was used for this experiment. Figure 2 provides an overview of the test track.
ACQUISITION OF PROBE DATA

Items of acquirable data on vehicle behavior and the acquisition cycle are shown in Table 1. Time, position, and directionality information at one-second intervals are items of data that can be acquired from general car navigation systems. Further, data on speed, acceleration (longitudinal and lateral), and yaw rate at 0.1-second intervals can also be acquired from the car navigation system modified for this experiment. The passenger vehicle used in this experiment is shown in Figure 3, and the installed condition of the on-board unit is shown in Figure 4. The data on vehicle behavior is generated by the car navigation system. It is then stored, and is acquired by a roadside DSRC unit as the vehicle passes by. The experiment was implemented on the assumption that data on vehicle behavior with respect to sudden deceleration, abrupt steering, and lane changing will appear as values differing from those for normal vehicle behavior.

### Table 1 Acquisition Interval (Cycle) for Data Items on Vehicle Behavior

<table>
<thead>
<tr>
<th>Data Items</th>
<th>Acquisition Cycle</th>
<th>Data Items</th>
<th>Acquisition Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position (latitude and longitude)</td>
<td>1.0 second</td>
<td>Speed</td>
<td>0.1 second</td>
</tr>
<tr>
<td>Time</td>
<td>1.0 second</td>
<td>Acceleration (longitudinal and lateral)</td>
<td>0.1 second</td>
</tr>
<tr>
<td>Direction (16 directions)</td>
<td>1.0 second</td>
<td>Yaw Rate</td>
<td>0.1 second</td>
</tr>
</tbody>
</table>

**Figure 3 Experimental Vehicle**

**Figure 4 On-board Equipment Installation**

**Experiment Related to Sudden Deceleration Behavior**

Sudden deceleration was implemented in accordance with the experimental procedures outlined below. Data items on vehicle behavior at that point of time were then acquired. For comparison with sudden deceleration behavior, normal deceleration was defined as the vehicle behavior when stopping at leisure in order to avoid collision with an obstruction ahead of the vehicle.

**Experimental Procedures**

1. Change the speed of approach (Vmax) to 40, 60, and 80km/h. Then implement the following steps 1 to 2 and 1 to 3 repeatedly at each Vmax.
2. Accelerate from the starting point, and pass Section A at the speed of approach (Vmax).
3. Step on the brakes so as to stop in front of an obstruction ahead of the vehicle (Normal deceleration).
4. Stop directly in front of the obstruction by applying full brakes (Sudden deceleration).
Experiment Related to Abrupt Steering Behavior

Abrupt steering was implemented in accordance with the experimental procedures outlined below. Data items on vehicle behavior at that point in time were then acquired. For comparison with abrupt steering, normal behavior was defined as that occurring when steering at leisure in order to avoid collision with an obstruction ahead of the vehicle.

**Experimental Procedures**

Change the speed of approach (Vmax) to 40, 60 and 80km/h. Then implement the following steps 1 to 2 and 1 to 3 repeatedly at each Vmax.

1. Accelerate from the starting point, and pass Section A at the speed of approach (Vmax).
2. Change lanes at leisure by steering around an obstruction at Section B (Normal Steering).
3. Maintaining the same speed, change lanes by abruptly steering around an obstruction at Section B (Abrupt Steering).

Experiment Related to Lane Changing Behavior

Lane changes were implemented on the assumption of avoidance of an obstruction well in advance, in accordance with the experimental procedures below. Data items on vehicle behavior were acquired at that point in time.

**Experimental Procedures**

Change the speed of approach (Vmax) to 40, 60, and 80km/h. Then implement the following steps 1 to 3 repeatedly at each Vmax.

1. Accelerate from the starting point, and pass Section A at the speed of approach (Vmax).
2. Maintain the same speed and then avoid the obstruction by changing lanes freely at the point that the obstruction at Section B is discovered.
3. Decelerate to a stop after avoiding the obstruction.
Analysis Results

Maximum values of acceleration and yaw rate were adopted for values of the behavioral measurement data among the data items on vehicle behavior in the analysis. Maximum values were used because those are considered to be parameters that straightforwardly indicate the behavior.

Data Analysis Results for Sudden Deceleration Behavior

Using data measured during sudden deceleration behavior, analysis was carried out of the maximum longitudinal acceleration distribution, obtained at each speed of approach.

As an example of a maximum longitudinal acceleration distribution, Figure 8 shows the results at an approach speed of 60km/h.

Table 2 shows the average value and standard deviation during normal and sudden deceleration, obtained from the acceleration distribution at each speed of approach. In addition, Table 3 shows the number of times the test was carried out.

Analysis

- The possibility was confirmed of discerning between sudden deceleration and normal deceleration from the maximum longitudinal acceleration values, at approach speeds of 40, 60, and 80km/h.
- It was confirmed that maximum longitudinal acceleration during normal deceleration was distributed on both sides around an average of approx. 0.4G, as previously reported for approach speeds of 40km/h and 60km/h.
- It was confirmed that the faster the speed of approach, the larger the maximum value for longitudinal acceleration.
Acceleration Obtained from Speed Acquired with a 1.0 Second Cycle

An investigation was implemented of the possibility of identifying sudden deceleration behavior using only acceleration values obtained by differentiating speed data with a 1.0 second cycle, which could be acquired easily from an ordinary car navigation system, without using 0.1 second acceleration data. Figure 9 shows an example of acceleration time series data for sudden deceleration behavior. The behavioral measurement is crude because of the acquisition cycle. However, it is evident that the maximum value for acceleration could be reproduced at virtually the same time. Additional investigation with a variety of patterns is required. However, the possibility was confirmed of identifying sudden deceleration behavior even from speed data with a 1.0 second cycle.

Table 4 shows the number of times the test was carried out, the average value, and the standard deviation during normal and abrupt steering, obtained from the maximum longitudinal and lateral acceleration distributions at each speed of approach.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Longitudinal Acceleration (G)</th>
<th>Lateral Acceleration (G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.27G</td>
<td>0.28G</td>
</tr>
<tr>
<td>Abrupt</td>
<td>0.37G</td>
<td>0.31G</td>
</tr>
<tr>
<td>Average</td>
<td>0.34G</td>
<td>0.33G</td>
</tr>
<tr>
<td>Standard Deviation Normal</td>
<td>0.042G</td>
<td>0.065G</td>
</tr>
<tr>
<td>Standard Deviation Abrupt</td>
<td>0.080G</td>
<td>0.148G</td>
</tr>
</tbody>
</table>

Figure 9  Comparison of Longitudinal Acceleration Obtained from Speed Differentiation

Data Analysis Results for Abrupt Steering Behavior

Using data measured during abrupt steering, analysis was conducted of the maximum longitudinal acceleration and maximum lateral acceleration distributions, obtained at each speed of approach. As examples of the maximum longitudinal and lateral acceleration distributions, Figure 10 shows the results at an approach speed of 60km/h.

Table 4 shows the number of times the test was carried out, the average value, and the standard deviation during normal and abrupt steering, obtained from the maximum longitudinal and lateral acceleration distributions at each speed of approach.

Figure 10  Maximum Lateral Acceleration and Maximum Longitudinal Acceleration Distributions at Vmax=60km/h
The difficulty of identifying abrupt steering from just the maximum longitudinal acceleration during abrupt steering was confirmed. This was because the difference from the maximum longitudinal acceleration during normal steering was small.

It was confirmed that for maximum lateral acceleration during abrupt steering, the difference from normal steering tends to be larger in comparison with the difference for maximum longitudinal acceleration.

**Data Analysis Results for Lane Changing Behavior**

Analysis of lane changing behavior was carried out using maximum yaw rate. Table 5 shows the number of times the test was carried out, and the average value and standard deviation for the maximum yaw rate for each speed of approach. For comparison, results are shown for straight-ahead driving and for abrupt steering.

<table>
<thead>
<tr>
<th>Vmax</th>
<th>Lane changing (deg/s)</th>
<th>Straight-ahead driving (deg/s)</th>
<th>Abrupt steering (deg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Samples</td>
<td>Average</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>40km/h</td>
<td>4</td>
<td>2.28</td>
<td>0.60</td>
</tr>
<tr>
<td>60km/h</td>
<td>4</td>
<td>1.38</td>
<td>0.54</td>
</tr>
<tr>
<td>80km/h</td>
<td>4</td>
<td>1.06</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Analysis**

- It is difficult to distinguish between the maximum yaw rate occurring during lane changing and that which occurs during straight-ahead driving, when the speed of approach is high. However, the possibility of discernment was confirmed when the speed of approach is low.
- It was confirmed that the maximum yaw rate during abrupt steering is extremely large in comparison with lane changing and straight-ahead driving, regardless of the speed of approach.
CONCLUSION

● Data obtained from car navigation systems (such as position, time, direction, speed, acceleration and yaw rate) was successfully up-linked via DSRC roadside units.
● The possibility was shown of detecting sudden deceleration behavior from maximum longitudinal acceleration.
● It was evident that with sudden deceleration behavior, the derivative value of speed data with a 1.0 second cycle could generally reproduce acceleration data with a 0.1 second cycle. With this result, the possibility was shown of implementing detection of sudden deceleration behavior using data easily acquired from ordinary car navigation systems.
● It was shown that with maximum lateral acceleration during abrupt steering, the difference from values during normal steering tended to be larger in comparison with that for maximum longitudinal acceleration.
● The possibility was shown of extracting lane changing behavior from maximum yaw rate when the driving speed was low.
● The possibility was evident of applying probe data for the creation of near miss maps and other services.

FUTURE STUDY

In this experiment, behavior data of ordinary vehicles was acquired from a limited number of drivers while driving on a dry test track, and was treated as basic data. In future, investigation of threshold values for the detection of hazardous phenomena will be necessary, as well as data acquisition and analysis under a variety of running conditions (consideration of driver characteristics, road surface conditions, large-size vehicles and other vehicle types, and road alignment).

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REFERENCES