INCIDENT DETECTION USING PROBE DATA
Determining Thresholds of a Near Miss

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KEYWORDS
AHS, Safety, Probe Data, Up-Link, Dedicated Short Range Communication (DSRC), Detection of Vehicle Behavior, Near Miss

ABSTRACT
A fundamental study has been conducted to realize an Advanced Cruise-Assist Highway System (AHS) service to detect near misses. The system would detect near miss behaviors from vehicle behavior data in order to monitor hazardous phenomena from a broad linear/planar perspective. A previous study discussed prospects for detecting near misses from data items that can be collected using car navigation systems. The current report presents an overview of experiments conducted to collect vehicle behavior data under diverse conditions. Specifically, information on road surface conditions, vehicle size, road category, and individual driver differences was correlated to vehicle behavior data, and the suitability of established threshold values is discussed.

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, cost constraints require that their installation is limited to locations where accidents frequently occur or where traffic is chronically congested. Therefore, an inexpensive system that can provide information on near misses, which are latent hazardous phenomena caused for example by a road construction and a stopped vehicle or fallen object on the road, to drivers and road administrators is necessary to resolve this issue. The system would monitor vehicle behavior over a wide area using probe data (3). Figure 1 shows a schematic diagram of such an AHS service using probe data. The system detects unusual behavior (sudden deceleration, abrupt steering) from multiple vehicles at the same location. Based on these data, the system can determine that a hazardous situation has arisen, such as the necessity to avoid a vehicle after an accident or a breakdown, a fallen object, etc.
Data on vehicle behavior from GPS receivers, acceleration sensors, and gyro-sensors utilized for car navigation systems are stored by an on-board unit, and are then transmitted via an up-linked to a road management center using dedicated short range communication (DSRC) roadside units. The road management center performs statistical processing to detect hazardous situations and to map out hazardous points. Information on upcoming hazards and road conditions that should be heeded can then be provided to following vehicles via DSRC roadside units in real time.

**Fig. 1 AHS Service Using Probe Data**

**OBJECTIVE**

This study defines near misses as "situations where unusual vehicle behavior occurs, such as sudden deceleration or abrupt steering". The purpose of this research is to detect hazardous vehicle behavior, such as sudden deceleration or abrupt steering from vehicle behavior data, and experiments were conducted to evaluate the thresholds and data items needed for this purpose. A prior study analyzed vehicle behavior data for a normal-size vehicle on a dry road surface, and confirmed the feasibility of judging near misses (4). The current study surveyed the characteristics of vehicle behavior data with regard to diverse conditions, such as various road surface conditions, vehicle categories including trucks, road categories, and individual driver differences. The experiments were conducted to confirm the validity of the set thresholds.

**TEST 1: Experiments Under Diverse Conditions**

Experiments were conducted using the test track of the National Institute for Land and Infrastructure Management (NILIM) of the Japanese Ministry of Land, Infrastructure and Transport to investigate the effects of road surface condition, vehicle category, driving speed, and individual driver differences. The vehicle behavior data items listed in Table 1 were collected from car navigation systems specifically developed for the experiments. Based on prior research, the data items were then organized using the peak values of longitudinal acceleration and lateral acceleration as representative values indicating vehicle behavior. In addition, vehicle behavior data were also collected through normal driving on public roads around Tukuba city in Ibaraki prefecture for comparison with the sudden deceleration and abrupt steering behavior data collected on the test track.
### Table 1 Vehicle Behavior Data

<table>
<thead>
<tr>
<th>Data item</th>
<th>Acquisition cycle</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1.0 s</td>
<td>1.0 s</td>
</tr>
<tr>
<td>Latitude/longitude</td>
<td>1.0 s</td>
<td>0.1 s</td>
</tr>
<tr>
<td>Speed (vehicle speed pulse)</td>
<td>0.1 s</td>
<td>0.1 m/s</td>
</tr>
<tr>
<td>Longitudinal acceleration</td>
<td>0.1 s</td>
<td>0.01G</td>
</tr>
<tr>
<td>Lateral acceleration</td>
<td>0.1 s</td>
<td>0.01G</td>
</tr>
<tr>
<td>Yaw rate</td>
<td>0.1 s</td>
<td>0.1 deg/s</td>
</tr>
</tbody>
</table>

### Experiments on test track

The following driving conditions were experimentally controlled.

- Water was sprayed on the test track to create a wet surface of 0.5 to 1.0 mm, and vehicle behavior was compared with behavior on a dry road surface.
- Vehicle behavior was compared among different test vehicle categories including a small-size, medium-size, and large-size vehicle.
- Vehicle behavior was compared for different approach speeds. 20 km/h was used to simulate congested conditions, 40 km/h for urban driving, 60 km/h for suburban driving, and 80 km/h for expressway driving.
- Vehicle behavior was compared among 10 test subjects to investigate the effects of individual driver differences.

The experiments on behavior during abrupt steering were performed by positioning obstacles assuming a headway time of 1.5 seconds, and having test subjects avoid the obstacles without braking. In addition, the experiments on behavior during sudden deceleration were performed by having drivers stop by simulating that a vehicle in front of them with a headway time of 1.5 seconds decelerated suddenly while cruising at constant speed (Figure 2).

*Evasion distance based on truck length (10 m)*
Results of test track experiment
As an example of results obtained from the test track experiment, a comparison of vehicle behavior data for dry and wet road surface is shown below. Lateral acceleration and longitudinal acceleration were taken as representative values indicating vehicle behavior during abrupt steering and sudden deceleration.
The cumulative curves in Figures 3 and 4 represent maximum values for lateral acceleration during abrupt steering, and longitudinal acceleration during sudden deceleration, respectively. The 85 percentile values are used for the wet/dry road surface comparison. As can be seen from the charts, there is almost no difference between the two conditions.

Abrupt steering behavior: Number of samples for each road condition: 298
Dry: 0.24 G  Wet: 0.21 G

Sudden deceleration behavior: Number of samples for each road condition: 150
Dry: -0.49 G  Wet: -0.51 G

Fig. 3 Cumulative Curves for Max. Lateral Acceleration During Abrupt Steering

Fig. 4 Cumulative Curves for Max. Longitudinal Acceleration During Sudden Deceleration
Table 2 provides a systematic listing of results obtained from the test track experiment. All values given for the various items are 85 percentile values. Judging from the characteristics of the collected acceleration data, no clear tendencies linked to road surface condition or vehicle size could be detected. For abrupt steering behavior, tendencies dependent on individual driver differences can be observed, while for sudden deceleration, the pertinent characteristics are cruising speed and individual driver differences.

<table>
<thead>
<tr>
<th>Item</th>
<th>Abrupt steering (max. lateral acceleration)</th>
<th>Sudden deceleration (max. longitudinal acceleration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road surface condition</td>
<td>0.24 G (dry)</td>
<td>0.49 G (dry)</td>
</tr>
<tr>
<td></td>
<td>0.21 G (wet)</td>
<td>0.51 G (wet)</td>
</tr>
<tr>
<td></td>
<td>→ Effect is small</td>
<td>→ Effect is small</td>
</tr>
<tr>
<td>Vehicle size</td>
<td>0.25 G (small-size)</td>
<td>0.46 G (small-size)</td>
</tr>
<tr>
<td></td>
<td>0.25 G (medium-size)</td>
<td>0.47 G (medium-size)</td>
</tr>
<tr>
<td></td>
<td>0.22 G (large-size)</td>
<td>0.45 G (large-size)</td>
</tr>
<tr>
<td></td>
<td>→ Effect is small</td>
<td>→ Effect is small</td>
</tr>
<tr>
<td>Cruising speed</td>
<td>0.22 G (20 km/h)</td>
<td>0.39 G (20 km/h)</td>
</tr>
<tr>
<td></td>
<td>0.22 G (40 km/h)</td>
<td>0.53 G (40 km/h)</td>
</tr>
<tr>
<td></td>
<td>0.25 G (60 km/h)</td>
<td>0.65 G (60 km/h)</td>
</tr>
<tr>
<td></td>
<td>0.25 G (80 km/h)</td>
<td>0.73 G (80 km/h)</td>
</tr>
<tr>
<td></td>
<td>→ Effect is small</td>
<td>→ Effect is speed dependent</td>
</tr>
<tr>
<td>Individual driver characteristics</td>
<td>Approx. 0.3 G variation range</td>
<td>Approx. 0.4 G variation range</td>
</tr>
<tr>
<td></td>
<td>→ Effect is dependent on individual driver differences</td>
<td>→ Effect is dependent on individual driver differences</td>
</tr>
</tbody>
</table>

Experiments on public roads
To examine vehicle behavior under normal driving conditions, data were collected while driving on different categories of roads (ordinary road, expressway, mountain road). Because the purpose was to collect data representing normal driving conditions, cruising speed was not predetermined but rather adapted to the prevailing traffic flow. Similar to the test track experiments, peak values of longitudinal acceleration and lateral acceleration were used to examine data characteristics.

Public road experiment results and setting of threshold values
Figures 5 and 6 show the distribution and average values of maximum longitudinal acceleration and lateral acceleration for different road categories (mountain road, ordinary road, urban expressway, interurban expressway) under normal driving conditions. The results demonstrate that steering action and deceleration values for expressways are small, while both tend to be large for mountain roads. It is therefore clear that road type dependent trends in acceleration change values exist.
Based on a symbolic representation of experimental data and public road data, the following statements can be made.

(1) Analysis of collected acceleration data did not show clear tendencies according to road surface condition and vehicle size, but tendencies according to cruising speed, road category, and individual driver differences could be observed.

(2) Maximum acceleration values obtained for expressways were smaller than for mountain roads and ordinary roads.

Judging from the above results, if near miss can be detected for expressways, where maximum acceleration values tend to be smaller than for ordinary roads or mountain roads, it
should be possible to then apply these thresholds also to these other kinds of road. To verify the suitability of threshold values for detecting near miss on expressways, and to absorb variations due to individual driver differences, the 85 percentile values of Table 2 were used. The final threshold values set below were arrived at by taking factors such as mounting precision of the on-board unit and sensor noise components into consideration.

**Threshold values**

- Lateral acceleration : ±0.22 G
- Longitudinal acceleration : -0.30 G

**TEST 2: Experiments to Verify the Validity of Thresholds**

Public road driving experiments were carried out on the Tokyo Metropolitan Expressway to verify whether the set thresholds are appropriate. In this test, a stretch of about 30 km in length was driven 126 times in both directions, and vehicle behavior data exceeding the thresholds were collected. Figure 7 shows a map on which points where the established thresholds were exceeded with a high frequency are plotted. Points with 10 events or more are shown in yellow and points with 60 events or more in red. All high accident points were also points with a high frequency of near miss. In addition, three latent near miss points were detected except high accident points.

These results indicate that the thresholds based on vehicle behavior data set according to TEST 1 are suitable for detecting high accident points as well as other points with a high latent probability for near misses.

![Fig. 7 Near Miss Map](Image)
To augment the data represented in the map shown in Figure 7, a survey among ordinary drivers about expectations and the perceived value of a safety information service was carried out (56 respondents). With regard to anticipated effects, more than 70 percent of the respondents thought that such a system would be "useful" or "somewhat useful". Many respondents commented that information about near miss points might easily be forgotten unless displayed on the car navigation system. The inclusion of such information in car navigation systems is therefore a topic that should be investigated further.

Over 80 percent of the respondents found the use of their own vehicles for collecting vehicle behavior data "not objectionable" or "not very objectionable". As a reason, many drivers stated their desire to "contribute to enhanced driving safety". It is therefore to be expected that collection of vehicle behavior data using the cars of ordinary citizens should prove widely acceptable.

CONCLUSION
The current study used vehicle behavior data collected from car navigation systems and examined the data characteristics under various conditions to evaluate the suitability of established threshold values. The following conclusions were reached.

(1) Analysis of collected acceleration data did not show clear tendencies according to road surface condition and vehicle size, but tendencies according to cruising speed, road category, and individual driver differences was observed.

(2) The threshold values obtained through experimental studies were suitable for detecting all high accident points on a given expressway section as well as for identifying other points with a high probability for near misses.

As a remaining issue, methods of providing such information have to be developed and effects on drivers have to be verified to evaluate the effectiveness of those services as a safety information service.

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