Abrupt Steering Detection Based on the Road Construction Ordinance and Vehicle Acceleration Captured with Drive Recorders

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Abstract

Risky steering operations are detected based on the relationship between the radius of road curvature and road design speed defined in the road construction ordinance. Vehicle motion while steering is approximated as a circular motion, and the vehicle trajectory radius is estimated from lateral acceleration and vehicle velocity captured with a drive recorder based on a circular motion equation. Steering operation behaviors are evaluated for 203 drivers. Experimental results show that the percentages of risky steering operations estimated for individual drivers correlate with driver risk evaluation scores given by a risk consulting expert. We also observed situations of risky steering by recording video along with driving data using a data collection vehicle.

1. Introduction

Drive recorders (DRs) or event data recorders (EDRs) are widely used especially in commercial fleets and transit vehicles such as taxis, buses, and delivery trucks [1]. When a triggering event occurs, such as an accident or abrupt acceleration, braking, or turning, images and vehicle acceleration signals are automatically recorded. Some drive recorders also capture average and maximum values of vehicle acceleration and velocity at short time intervals, e.g., once a minute.

Driving records are utilized in driver risk consulting as feedback about driving performances to drivers to reduce risky driving behaviors. A risk consulting company reported that about 30 to 80% of traffic accidents could be reduced by mounting drive recorders on vehicles and informing drivers using the results of data analysis. However, driver evaluation is time-consuming because it requires manual data analysis by risk consulting experts.

In this paper, an automatic driver evaluation method is proposed for evaluating the steering behaviors of drivers. Conventional drive recorders detect risky driving events when vehicle acceleration exceeds a certain threshold, e.g., 0.3 G. However, sudden steering at a high speed is more dangerous than at a low speed. This means the threshold depends on vehicle velocity. To consider this issue, we detect risky steering based on the Japanese road construction ordinance [2] that defined the relationship between the minimum radius of road curvature and road design speed. Driving data recorded once a minute including the maximum values of vehicle lateral acceleration and velocity at the time are used for driver evaluation. Vehicle motion while steering is approximated as a circular motion, and the vehicle trajectory radius is estimated from the right or left lateral acceleration and vehicle velocity based on a circular motion equation. Steering with a smaller radius of curvature than the threshold defined in the road construction ordinance is assumed to be risky. Steering operation behaviors are evaluated for 203 drivers who drove more than 25 hours. The results of steering behavior evaluation are compared with driver evaluation scores graded by a risk consulting expert.

We also recorded video along with driving data using our own data collection vehicle equipped with various sensors [3] to monitor risky steering.

Table 1 Relationship between road design speed and minimum radius of curvature defined in Japanese road construction ordinance

Road design speed [km/h]	Minimum radius of road curvature [m]
20	15
30	30
40	60
50	100
60	150
80	280
100	460
120	710

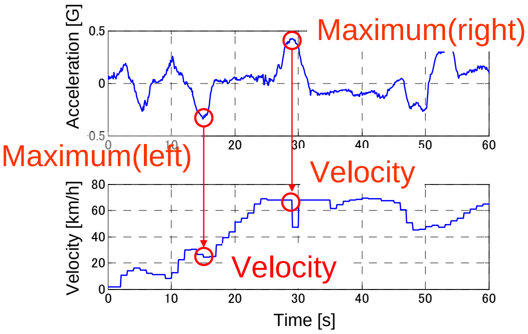

Fig.1 Maximum lateral acceleration and velocity recorded once a minute with driver recorder

2. Evaluation of steering behaviors

2.1. Risky steering detection

The minimum radius of road curvature depends on road design speed, which is specified in the road construction ordinance No. 15 [2]. Table 1 shows the relationship between the radius of curvature and road design speed. We approximate vehicle motion while steering as a circular motion and estimate the radius of the curvature of vehicle trajectory R [m] based on a circular motion equation:

$$R = \frac{v^2}{a}, \quad (1)$$

where a [m/s^2] is right or left lateral acceleration and v [m/s] is velocity. We assume that steering with a smaller radius of curvature than that of Table 1 is risky.

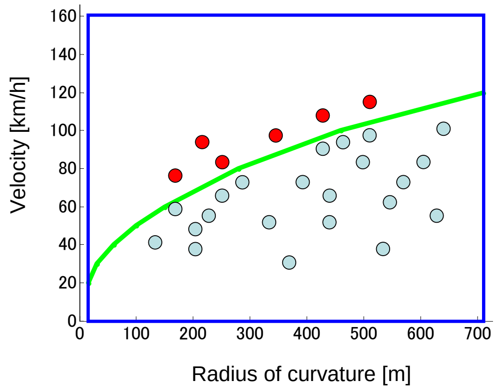

Fig.2 Two-dimensional map of vehicle velocity and radius of curvature

2.2. Driver evaluation

Using driving data provided by a risk consulting company, we evaluated the steering behaviors of 203 drivers that included maximum right and left lateral acceleration measured with a gyroscope and GPS velocities recorded once a minute (Fig. 1). Drivers drove more than 25 hours in good GPS conditions. The radius of curvature were estimated from acceleration and velocity pairs and plotted on a two-dimensional map of velocity and radius (Fig. 2). The risk level of the steering behaviors of each driver was evaluated from the data plots. We assumed the plots exceeding the threshold line derived from Table 1 to be risky steering operations. Figure 3 shows examples of two-dimensional maps for four different drivers. The upper and lower halves illustrate the steering operations to the left and right, respectively. Distributions of the dots on the left and right halves are nearly symmetrical and different among drivers. The percentages of risky steering for Drivers 1-4 were 60, 38, 15, and 0.2%, respectively. We assume that Driver 4's steering is the safest among the four drivers.

3. Validation of the proposed method

Along with driving data, driver evaluation scores from 1 to 5 (from safe to risky) for individual drivers graded by a risk consulting expert were also provided. We compared the percentages of risky steering with the driver evaluation scores. Figure 4 shows the distribution of drivers by percentage of risky steering. We can see the correlation between the driver evaluation scores and the percentages of risky steering, i.e., drivers with lower scores are distributed at lower percentages and drivers with higher scores are distributed toward higher percentages.

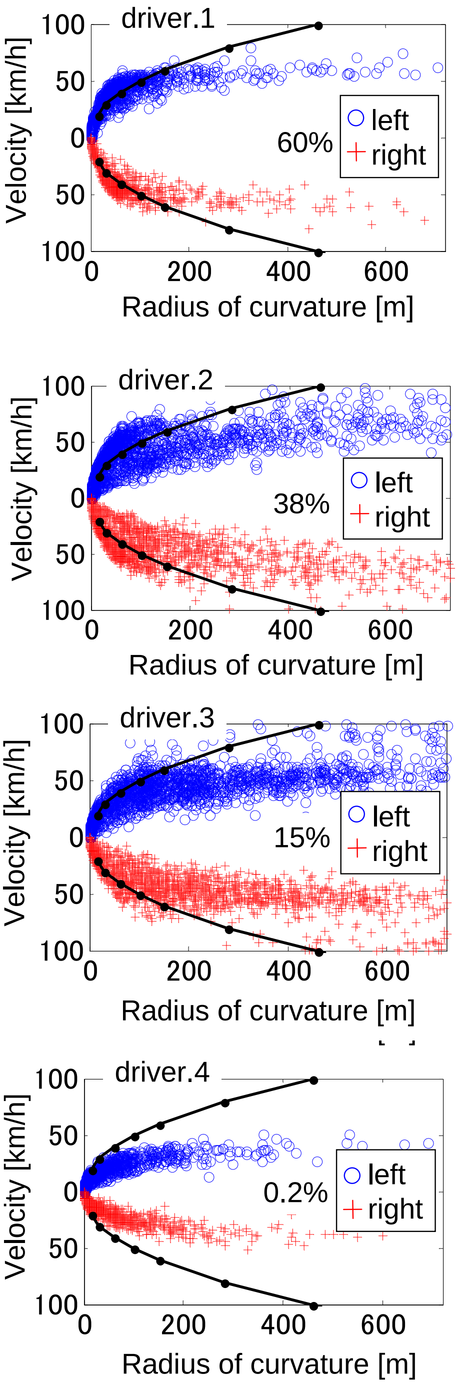

Fig.3 Examples of two-dimensional maps of velocity and radius of curvature for four different drivers

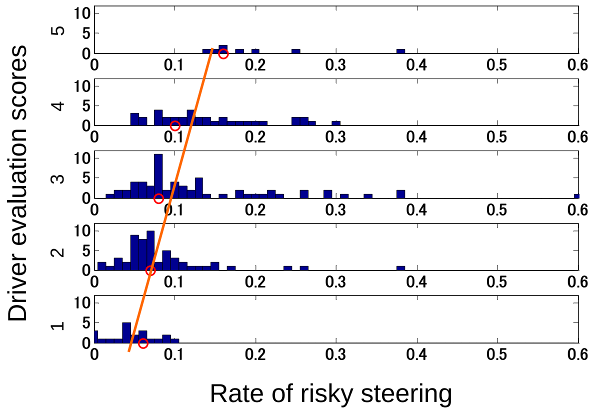

Fig.4 Distribution of drivers of rate of risky steering for each level of driver evaluation score 1-5

Fig.5 Data collection vehicle used for recording video

4. Further situation analysis with video records

The driving data used so far do not include video data. To see the situations of risky steering we recorded video along with driving data using our own data collection vehicle (Fig. 5). The data collection vehicle is equipped with various sensors including an acceleration sensor, four cameras, 12-ch microphones, gas and brake pedal pressure sensors, physiological sensors, etc. [3].

Each driver drove for one hour on city roads and an expressway near Nagoya University. The route for data collection is shown with green and blue lines on the map in Fig. 6. Lateral acceleration data were recorded at 16 kHz and down-sampled at 10 Hz. The same risky steering detection method was applied to our own driving data.

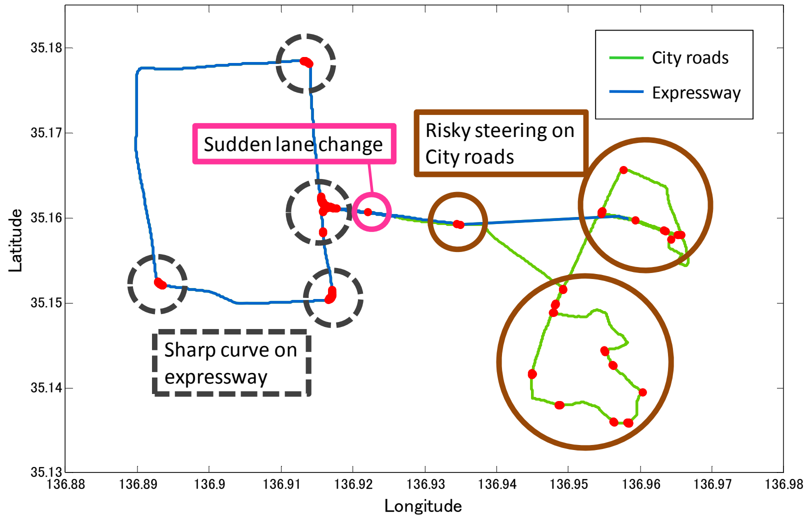

Fig.6 Driving route for data collection: risky steering operations detected at places with red dots

We detected 76 risky steering behaviors for eight drivers. Places where risky steering behaviors were detected are shown with red dots in Fig. 6. We monitored the scenes recorded on video when risky steering behaviors were detected. Some were recorded on sharp curves on the expressway, and others were detected while turning on city roads. One was detected when a driver suddenly changed lanes at a fork in the expressway. They also included some detection errors caused by bumpy spots on the roads.

5. Conclusion

In this paper, the steering behavior of drivers was evaluated based on the relationship between the radius of road curvature and road design speed defined by the Japanese road construction ordinance. The vehicle trajectory radius while steering was estimated based on a circular motion equation, and drivers were evaluated on two-dimensional maps of velocity and radius of curvature. Experimental results showed that the percentages of risky steering operations correlated with driver risk evaluation scores given by a risk consulting expert.

Future works include reduction of detection errors using dynamic features of driving signals and integration of risky acceleration and braking detection methods with the proposed risky steering detection method.

Acknowledgements

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References

[1] DriveCam, http://www.drivecam.com/.

[2] Road Construction Ordinance No.15, http://www.mlit.go.jp/road/sign/kijyun/kozou/ss-kozou.html#kozo15 (in Japanese).

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