

DEVELOPMENT OF DRIVING STABILITY SCALE WITH G-G DIAGRAM AND ISOLATION FOREST ALGORITHM

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1. INTRODUCTION

Many studies have attempted to model driving behavior from the perspective of driving safety. Acceleration and braking behavior have been the most significant for a quantitative evaluation of unsafe or aggressive driving styles. One way for analyzing driving safety is g-g diagram that shows lateral and longitudinal accelerations on the x and y-axes. As the acceleration shown in the diagram is measured in units of G, the plot is called g-g diagram. The diagram was proved to be an effective way for measuring vehicle-driver performance as the two axes of accelerations can be seen as the driving behavior selected according to driver's motion perception and the risk level he or she accepts (Da-liao et al.). Hisaoka et al. utilized the g-g diagram to evaluate vehicle-driver performance, wherein a capability index was developed to differentiate skilled drivers and novice drivers. Vaiana et al. defined a safe area in the g-g diagram considering driving experience and friction force; the percentage of points outside the safe area was used to classify drivers into aggressive and non-aggressive groups.

Development of GPS technologies and driving record devices makes it possible to collect abundant driving behavior data. This study investigates driver's acceleration driving style (ADS) learning from their actual driving records continuously collected by driving recorder installed in their vehicles. The larger the number of records produces the better understanding for the driving behavior. However, huge record data is time consuming for the data process. This study applies one of the machine learning methods, the isolation forest algorithm, to extract driver's ADS efficiently. Based on the extracted ADS diagrams, five indicators were calculated to measure driver's acceleration and braking driving performance. These indicators can reflect driving stability of a driver. A factor analysis is executed to develop a driving stability scale (DSS) from the five indicators.

2. METHODOLOGY

Each driver has his/her own driving style, which is the general manner of the driver's driving behavior. In the g-g diagram, driver's ADS can be represented by dense acceleration data points as these points are more likely to occur compared to sparse points. Therefore, isolation forest algorithm was used to extract a certain percentage of points which are most likely to occur. The isolation forest algorithm detects sparse points using isolation based on the idea that sparse points tend to be far from the rest of samples (Liu et al.). The extracted points were plotted in the g-g diagram to form driver's ADS diagram. The percentage of points to be extracted was set to be 99% in

this study as this value can exclude most sparse points which indicate lower probabilities of occurrence and thus cannot be considered as driver's driving style. As shown in Figure 1, sparse points were excluded after performing isolation forest algorithm on the raw data. The distribution of lateral acceleration and longitudinal acceleration can be investigated by the ADS diagram.

Five indicators were calculated from ADS diagram to measure the acceleration and braking driving performance: 1) maximum left-hand cornering acceleration from the positive values of the lateral acceleration; 2) maximum right-hand cornering acceleration from the negative values of the lateral acceleration; 3) maximum longitudinal acceleration; 4) maximum longitudinal deceleration; and 5) inertia. The first two indicators evaluate the performance of driver's lateral maneuvers while 3) and 4) measure longitudinal maneuvers. Inertia is the average distance from each data point to the centroid of all plots. These values can reflect the driver's driving stability. Larger maximum values and larger inertia means more unstable driving because of larger variation in accelerations

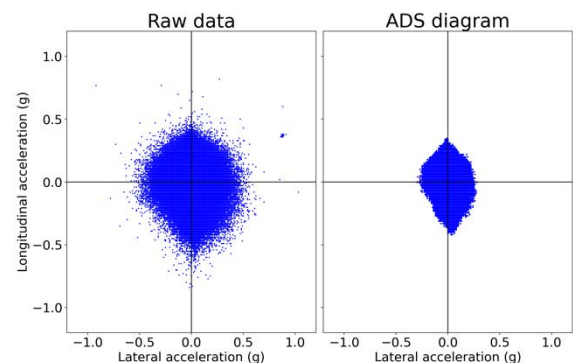


Fig. 1 g-g diagram before and after isolation forests

3. DATA DESCRIPTION

The data used in this study were obtained from the elderly driver's database of the Nagoya University Center of Innovation (COI) project, aiming to empower an aging society using advanced mobility. Since February 2015 to February 2019, the daily driving records of 84 individuals whose age ranges from 50 to 85 years old have been collected using the drive recorder (DR) equipped in their vehicles. The DR data collected the timestamp, velocity, acceleration, and GPS location of the vehicle with a frequency of 1 s.

4. RESULTS

The ADS diagram of each driver was extracted by the

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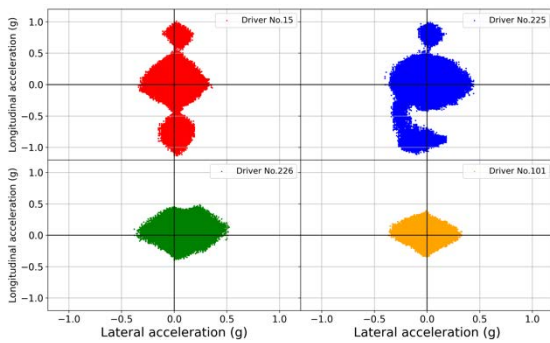


Fig. 2 Examples of ADS diagrams

isolation forest algorithm. Figure 2 shows examples of four drivers' ADS. Drivers 15 and 225 perform highly unstable driving compared to others. Both drivers exhibit much harder longitudinal acceleration and deceleration. In addition, driver 225 often perform hard deceleration during right-turn maneuvers. In contrast, drivers 101 and 226 gives quite stable driving although driver 226 is relatively easy to exhibit hard left-turn maneuvers.

The factor analysis was executed to develop a driving stability scale (DSS) from the five indicators. Cronbach's alpha for the five indicators is 0.86, which indicates good internal consistency of the five indicators. Through the exploratory factor analysis, the Bartlett's test was significant with χ^2 p-value =0.000. KMO=0.74, which means these variables are acceptable for 1 factoring. A confirmatory factor analysis (CFA) was conducted to further check the internal consistency reliability of the five indicators. The CFA results are shown in Figure 3. All path coefficients are statistically significant at the 0.1% level. The goodness of fit indices suggests a good fit to the data ($\chi^2(5, N=84) = 26.42, p < 0.01, CFI=0.91, TLI=0.83, RMSEA = 0.226$).

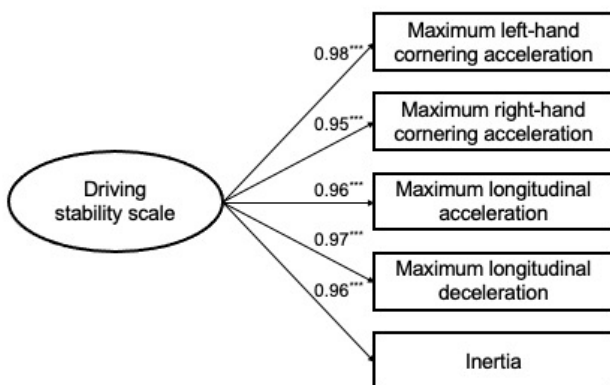


Fig. 3 CFA results, n=84

The DSS score was created by the factor score of the five indices. The distribution of DSS scores is shown in Figure 4. The maximum value of DSS is 0.498 and the minimum value is -0.064. 91.67% of drivers are lower than 0.05. The DSS scores for the four drivers in Figure 2 are 0.174, 0.156, 0.069 and -0.008 respectively. Higher DSS score indicates more unstable driving. The two unstable drivers show considerably higher score than the stable drivers.

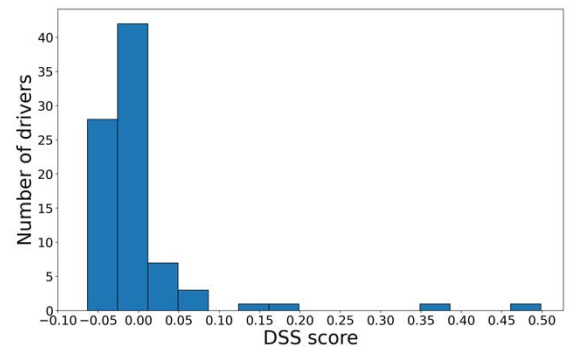


Fig. 4 Distribution of DSS score

4. CONCLUSION

This study developed a scale to describe driving stability according to the ADS of drivers. The isolation forest algorithm can successfully extract ADS diagram providing measurement indices for the DSS. The CFA results showed that all the indicators are reliable to measure the DSS. Plot of the ADS diagram can also help understand driving stability and its differences among drivers intuitively. In addition to acceleration, jerk is often considered as a risky driving factor. Therefore, it is worth examining jerk for the DSS in the future study. Furthermore, the relationship between DSS, the individual characteristics and risky driving indices are expected in the future work.

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