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Driver Attribute Classification Method Based on Driving Behavior

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ABSTRACT

This study develops a method for classifying driver attributes based on driving behavior, to create a driving support system that enhances safety and comfort. Unlike traditional methods that rely on check sheets for accurate but delayed attribute classification, this study focuses on immediate and flexible classification. A driving simulator was used to predict driver attributes through a multiple regression analysis of the driving log, which recorded vehicle behavior during driving. The results were then applied to facilitate harmonious interactions between the driver and the system, particularly in environments involving automated driving levels 2 and 3, where the driver remains engaged in the driving operation. The findings of this study will contribute to the development of driving assistance systems that consider driver attributes and behaviors in the context of automated driving, to create safer and more comfortable driving environments.

Keywords: Driver attribute classification, Driving style check sheet, Driving workload sensitivity check sheet, Driving behavior

INTRODUCTION

In recent years, automobiles have become indispensable conveniences in society; however, they can also be dangerous, causing fatal accidents. To ensure safety within the automobile industry, various safety measures have been implemented in Japan since 2000. Mandates such as seatbelts, airbags, and anti-lock braking systems (ABS) (passive safety) have helped mitigate the damage caused by accidents. Furthermore, the proliferation of preventive safety features in recent years, such as collision avoidance braking (active safety), has led to a proactive reduction in the occurrence of traffic accidents. The effectiveness of these technological developments and regulatory efforts is evident in the trends observed in metrics such as the number of traffic accidents and casualties (Cabinet Office, 2019).

Currently, the development of autonomous vehicles is being pursued to further reduce traffic accidents and achieve smooth flow of traffic. According to the Government-Private ITS Concept and Roadmap 2019, autonomous driving is divided into five levels. In terms of practical implementation, autonomous driving falls within levels 2 and 3, where drivers are required to control the vehicle through steering and pedal operations, depending on the situation. In other words, individuals engage in driving operations as drivers, while the vehicle provides support, and a driver-centric automotive system is sought (Government CIO's Portal, 2019).

Therefore, this study aims to provide a safer and more comfortable driving environment by allowing drivers to benefit from a driving assistance system without experiencing discomfort. This study's goal is to develop a method for estimating driver attributes (safety, driving aptitude, and system dependency) considering practical implementation, using information that the vehicle can acquire. In addition, the effectiveness of this approach is examined.

DRIVER ATTRIBUTES AND CLASSIFICATION

A "Driving Style Check Sheet" for subjectively evaluating individual differences in daily driving behavior and a "Driving Workload Sensitivity Check Sheet" for understanding driver-specific characteristics related to driving assistance have been developed by Akamatsu et al. (2004). Although it lacks immediacy, this methodology can be considered a useful reference for individual driver traits. Additionally, a correlation has been demonstrated between the Driving Style Check Sheet and safety verification behaviors during driving (surroundings checked through head movements), suggesting that driver-specific traits assessed by the check sheets may manifest in driving operations.

Driver attributes (safe driving aptitude and system dependency) were classified using driving behavior parameters, derived from driving logs obtained during driving simulator (DS) sessions.

Driving Style Check Sheet

The Driving Style Check Sheet is a questionnaire comprising 18 questions regarding attitudes, inclinations, and thought processes during daily driving. The responses are divided into four levels: "Does not apply," "Slightly Applicable," "Fairly Applicable," and "Highly Applicable" (Akamatsu et al., 2004) (see Appendix I for the questionnaire). Unlike conventional driver attribute classifications based on factors such as gender, age, and experience, this checklist has been developed to focus on the driver's internal characteristics. Based on the analysis of numerous previous studies (French et al., 1993, Taubman-Ben-Ari et al., 2004, West et al., 1993) on individual driving styles, the questionnaire consisted of the following eight dimensions:

- Confidence in driving skills
- Passive attitudes toward driving
- Impatient driving tendencies
- Methodical driving tendencies
- Preparatory driving for traffic signals
- Car as a status symbol
- Unstable driving tendencies
- Anxious tendencies

Notably, the scores are treated as a metric for "Safe Driving Aptitude" after being quantified because the Driving Style Check Sheet measures how much an individual emphasizes safe driving in their usual driving behavior.

Driving Workload Sensitivity Check Sheet

The Driving Workload Sensitivity Check Sheet is a questionnaire comprising 38 questions about handling behaviors in one's daily route selection and challenging driving environments. The responses are divided into five levels: "Driving without concern," "Driving attentively without feeling burdened," "Feeling a slight burden while driving," "Experiencing a significant burden due to tension or pressure," and "Feeling such a significant burden that you do not want to drive" (Akamatsu et al., 2004) (see Appendix II for the questionnaire results). This checklist has been developed to extract driver sensitivity to perceived burdens as driving characteristics, not only based on interactions with other drivers, as traditionally indicated, but also by asking about various stressors, such as accident experiences and road conditions. Therefore, based on previous studies (Gulian et al., 1989, Hill and Boyle, 2007, Kontogiannis 2006, Horberry et al., 2006) on how individual drivers perceive stress and burdens, the questionnaire consists of the following ten dimensions:

- Perception of traffic conditions
- Perception of the road environment
- Hindrance to concentration when driving
- Decreased physical activity
- Hindrance to driving pace
- Physical discomfort
- Route understanding and exploration
- In-car environment
- Control operations
- Driver's posture

In this study, because the Driving Workload Sensitivity Check Sheet measures the susceptibility of an individual to feeling burdened during regular driving, there might be a tendency to rely on the system in situations of increased burden. Therefore, after quantification, the scores are treated as a metric called System Dependency.

METHODOLOGY

The driving experiment was conducted using a DS (HONDA, DS-01). The driving course consisted of urban areas transitioning to mountainous sections; it included interactions with other vehicles, pedestrians, signals, and six types of hazardous events. The DS utilized automatic transmission (AT) to simulate clear and dry weather conditions. The participants were 15 university students (7 males and 8 females) between 20 and 23 years of age, all holding regular automobile licenses with AT transmission capabilities or higher. The experiment was conducted after obtaining written consent from the participants after sufficient explanation of the experiment content. Also, they underwent prior familiarization with DS operations.

They drove in a comfortable posture while obeying traffic regulations, representing their usual driving state, without the use of sensors or other equipment. The entire experiment lasted for approximately one hour with driving sessions of approximately 10 min each.

The experimental procedure on the day of testing is illustrated in Figure 1.

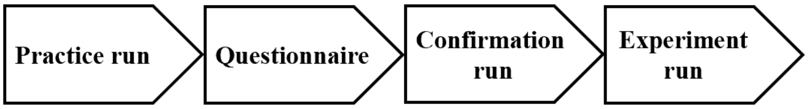

Figure 1: Experimental schedule.

Evaluation Indices

A two-dimensional coordinate system was constructed by plotting a safe driving aptitude score obtained from the Driving Style Check Sheet on the vertical axis, and system dependence score obtained from the Driving Workload Sensitivity Check Sheet on the horizontal axis. Thus, each driver's observation point was plotted, enabling the confirmation of their quadrant (Figure 2).

The quadrant to which each driver belonged based on the driving logs were predicted. These driving logs included 16 variables extracted from experimental driving, such as vehicle speed and brake frequency, which were used as driving behavior parameters. Notably, the predictions made from the driving logs were conducted separately for the safe driving aptitude and system dependency attributes.

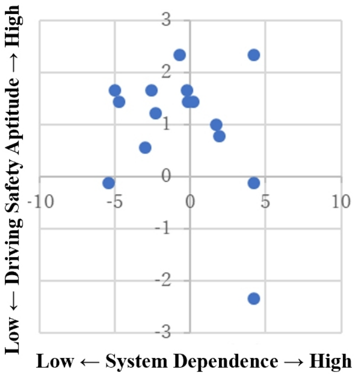

Figure 2: Driver attribute distribution.

RESULTS AND DISCUSSION

A multiple regression analysis was performed, with the objective variables being the scores for safe driving aptitude and system dependency, and the combinations of driving behavior parameters as explanatory variables. The results of the predictive model using the optimal parameters are presented below.

Equation (1) represents the predictive model for safe driving aptitude.

$$y_1 = 5.783 - 0.134x_1 - 0.113x_2 + 0.006x_3 - 0.036x_4 \qquad (1)$$

where, y_1 is safe driving aptitude, x_1 is red signal accelerator-brake transition time, x_2 is brake frequency, x_3 is pedestrian-crossing intersection passage time, and x_4 is brake opening degree mode.

Equation (2) represents the predictive model for system Dependency.

$$y_2 = 6.910 - 0.157x_1 - 2.079x_2 \tag{2}$$

where, y_2 is system dependency, x_1 is red signal braking time, and x_2 is number of accidents.

Cross-validation was performed to assess the accuracy of the predictive models for each driver attribute. For each of the participants, a multiple regression equation was derived using the data from the other 14 participants, which was then used to predict and classify the one remaining participant. Tables 1 and 2 present the results of the accuracy validation for each driver attribute prediction.

Table 1. Accuracy validation for safe driving aptitude.

		Predicted value	
		High	Low
Questionnaire	High	11	1
	Low	1	2

Correct answer rate = 0.87, Precision = 0.92, and Recall = 0.92

Table 2. Accuracy validation for system dependency.

		Predicted value	
		High	Low
Questionnaire	High	5	1
	Low	4	5

Correct answer rate = 0.67, Precision = 0.56, and Recall = 0.83

Based on Tables 1 and 2, it can be observed that the prediction accuracy of the safe driving aptitude was quite high. However, there is room for improvement in the predictive accuracy of system dependency, which serves as a metric indicating the extent to which drivers seek driving assistance and is distinct from driving workload sensitivity. In other words, it is a measure to enhance driving comfort beyond safe driving aptitude alone. For vehicle safety, it is important to emphasize recall to ensure that drivers who desire the system receive assistance. However, focusing solely on recall may lead to concerns about a decrease in user experience among drivers who do not wish for system intervention. Therefore, for a more comfortable driving environment, it is necessary to re-evaluate the system dependency prediction model to increase precision while maintaining recall. Furthermore, a common aspect among the explanatory variables of the prediction model was the presence of actions and behaviors related to deceleration, such as brake operations. These driving behavior parameters were correlated ($R > 0.4$) with each driver attribute. This suggests that the tendencies of individual driver characteristics are more likely to manifest during deceleration-related driving actions and vehicle behaviors. Consequently, collecting a greater number of deceleration-related driving behavior parameters could improve the accuracy of driver attribute prediction models.

CONCLUSION

To summarize the results, the following points constituting the conclusions were drawn:

1. It was proposed to predictive models for two types of driver attributes (i.e., safe driving aptitude and system dependency) based on DS logs. This enables the automatic provision of safe and comfortable driving assistance systems from the vehicle to any driver, considering their awareness of safe driving and tendencies toward utilizing driving assistance systems.
2. The driver attribute types were found to correlate with actions and behaviors related to deceleration, such as braking. This suggests that individual driver characteristics are more likely to manifest during deceleration-related driving actions, thereby enhancing the understanding of driver behavior.

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