

Evaluation of Driver Operation Variability for the Interpretation of Machine Learning-Based Pedal Operation Predictions

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In recent years, Acceleration Control for Pedal Error (ACPE) systems have been developed and implemented as a countermeasure against accidents caused by accidental pedal misapplication. However, current ACPE systems have limitations in their operating conditions, and there is a need to develop ACPE systems capable of responding to a wider range of driving situations. As one approach to realizing this, the use of machine learning to predict pedal operation is being investigated. In machine learning, models are trained under the assumption that drivers will perform similar operations under the same conditions, and their performance is evaluated using data different from that used for training. However, even under identical conditions, a driver's pedal operation exhibits variability due to probabilistic characteristics. Therefore, when there is a difference between the model's prediction and the driver's actual operation, it is difficult to determine whether the predicted operation was within the range of the driver's operational variability. Therefore, in order to appropriately evaluate the accuracy of machine learning-based pedal operation predictions, it is necessary to evaluate the variability in driver operations under the same conditions.

Data were collected using a driving simulator (DS). Twenty-one participants in their 20s (20 men and 1 woman) who held valid driver's licenses took part in the experiment. Participants were instructed to decelerate to avoid a collision when approaching a forward vehicle. The participants' vehicle speed was fixed at 40 km/h, and trials were conducted under two conditions for the forward vehicle: "stationary" and "traveling at 30 km/h." Each participant performed 10 trials under each condition.

Trial pairs in which the difference in time to collision (TTC) at the start of braking was 0.1 seconds or less were selected to evaluate the similarity of braking operations. Similarity was evaluated using the coefficient of determination (R^2), root mean square error (RMSE), dynamic time warping (DTW), integral of absolute error (IAE), and the absolute difference in area under the curve (AUC). Normalized values were used for DTW, IAE, and AUC. Waveform similarity was evaluated over a 1-second interval starting from the initiation of braking. Table1 showed the 25th, 50th, 75th, 80th, 90th, and 95th percentile values for each metric. To calculate R^2 , data from the earlier trial were treated as the waveform predicted by the machine learning model, while data from the later trial were treated as the evaluated waveforms. Taking into account the degree of variation shown in Table1 prevents false activations when applying machine learning to the detection of pedal misapplications. As shown in Table1, negative R^2 values were observed in more than one-quarter of all trial combinations. For the pairs of trials where the R^2 value was negative, Figure1 showed the braking operation during the evaluation interval, and Figure2 showed the data over the entire braking operation period. As shown in Figure2, in the operation shown by the blue line, the pedal stroke increased rapidly and reached its peak in a short time, compared to the operation shown by the orange line, where a low pedal stroke was kept for a longer period before increasing and reaching its peak. These results indicated that the two braking maneuvers showed different characteristics throughout the maneuver duration. Therefore, since multiple braking behavior patterns may exist even under the same driving conditions, it is necessary to take such variability into account when using machine learning to predict braking maneuvers.

Table1 Percentile values of evaluation metrics

	R^2	RMSE	Normalized DTW	IAE per second	Difference AUC per second
25 %	-0.183	0.0967	0.0236	0.0843	0.0797
50 %	0.554	0.0633	0.0099	0.0551	0.0495
75%	0.838	0.0434	0.0052	0.0380	0.0260
80 %	0.871	0.0404	0.0042	0.0341	0.0205
90 %	0.926	0.0300	0.0030	0.0235	0.0090
95 %	0.948	0.0224	0.0022	0.0182	0.0036

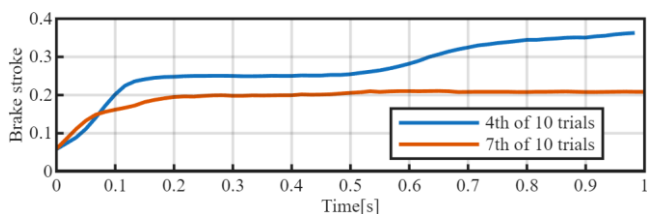


Fig.1 Comparison of braking operations within the one-second period from the start of operation

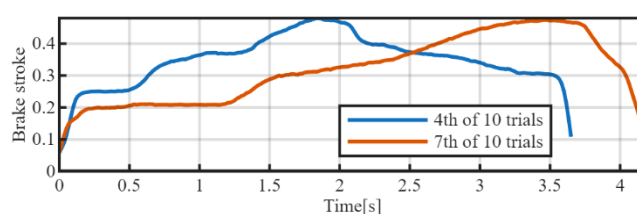


Fig.2 Comparison of braking operations during the entire experimental period