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A Study on Construction of LSTM Models for Overtaking Behavior

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A driver model is expected to reduce the sense of nuisance of passengers to advanced driver assistance systems (ADAS) and automated driving systems. This study aimed to construct driver models in overtaking scenario using Long Short-Term Memory (LSTM) model which was one of neural network models, to evaluate the model accuracy and to verify whether LSTM models could reflect the individual characteristics for each driver. LSTM is one of RNN and is good at learning long-term time series data.

We conducted the experiment to obtain the driving data for 10 times using driving simulator. The outputs of LSTM models were longitudinal and lateral velocities. The model accuracy was evaluated for both longitudinal and lateral directions, which was based on the results of the smallest Root Mean Squared Error (RMSE) in the highest model accuracy (Min. RMSE), and the those of the largest RMSE in the lowest model accuracy (Max. RMSE). In this experiment, the Tomei Expressway between Gotemba and Ayusawa was simulated, and a Toyota Prius was used as the ego vehicle. The lane width [A] was 3.5 m from the geometry and the ego vehicle width [B] was 1.76 m, as shown in Fig. 1. The lateral error that the ego vehicle departed from the lane was calculated using Equation (1). The lateral error [C] in this study was 0.87 m. The smaller the error indicated that the model accuracy was the better evaluation. However, the model accuracy required that the vehicle did not depart from the lane. Therefore, in order to evaluate the error of the model, we evaluated whether the model departed from the lane as a minimum requirement.

$$C = \frac{1}{2} \times (A - B) = \frac{1}{2} \times (3.5 - 1.76) \cong 0.87 \text{ m} \tag{1}$$

The RMSE could be used to evaluate the model accuracy. However, in order to evaluate whether the vehicle was traveling in the lane without departing from the lane, the positional accuracy in each of the longitudinal and lateral directions was calculated as the error distance. Therefore, the maximum error distance was calculated in both the longitudinal and lateral directions. To verify whether the LSTM driver model reflects individual characteristics, first we selected the training data of one experimental participant, and constructed a model of this participant using the hyperparameters with the highest model accuracy (Min. RMSE). Next, RMSE was calculated using data of different participants for evaluating the reflection of individual characteristics in the constructed model.

We constructed driver models using LSTM as shown in Table1. The max. error distance in longitudinal direction was within 0.3 m in the Min. RMSE of the high model accuracy, and was 0.160 m in the Max. RMSE of the low model accuracy. The constructed model did not have a large error that the vehicle departs from the lane. Since the average RMSE was larger than RMSE of Min. RMSE, it was possible to construct a model for each individual with high accuracy, where the LSTM model reflected the individual characteristics of the drivers.

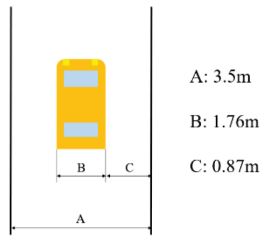

Fig.1 Lateral error which LSTM models do not overhang the lane

Table1 LSTM Model Accuracy in RMSE

Participant	Direction	Min. RMSE [m]		Max. RMSE [m]		Average RMSE when applying different participants data*2[m]
		RMSE	Max. error distance*1 [m]	RMSE	Max. error distance*1 [m]	
Average	Longitudinal	0.053	0.235	1.051	3.736	0.692
	Lateral	0.008	0.031	0.066	0.160	0.087

*1: This value is the largest error distance among the models with the highest and lowest accuracy for each participant.
*2: This is the average RMSE when training with the hyperparameters of the best accuracy model for each participant and using the other participants' data as test data.