Driver Model for Shared Control

Partner: JTEKT Corporation
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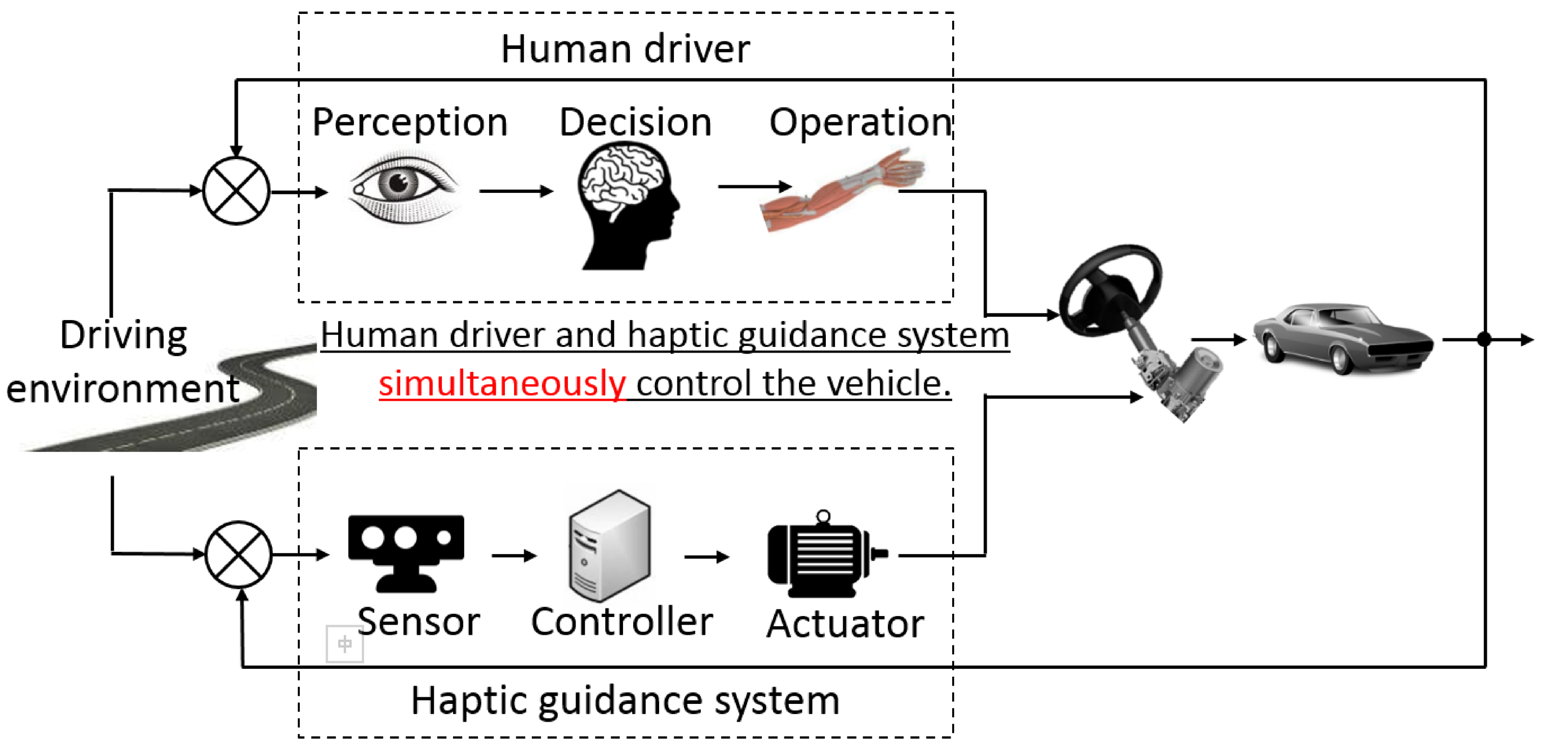
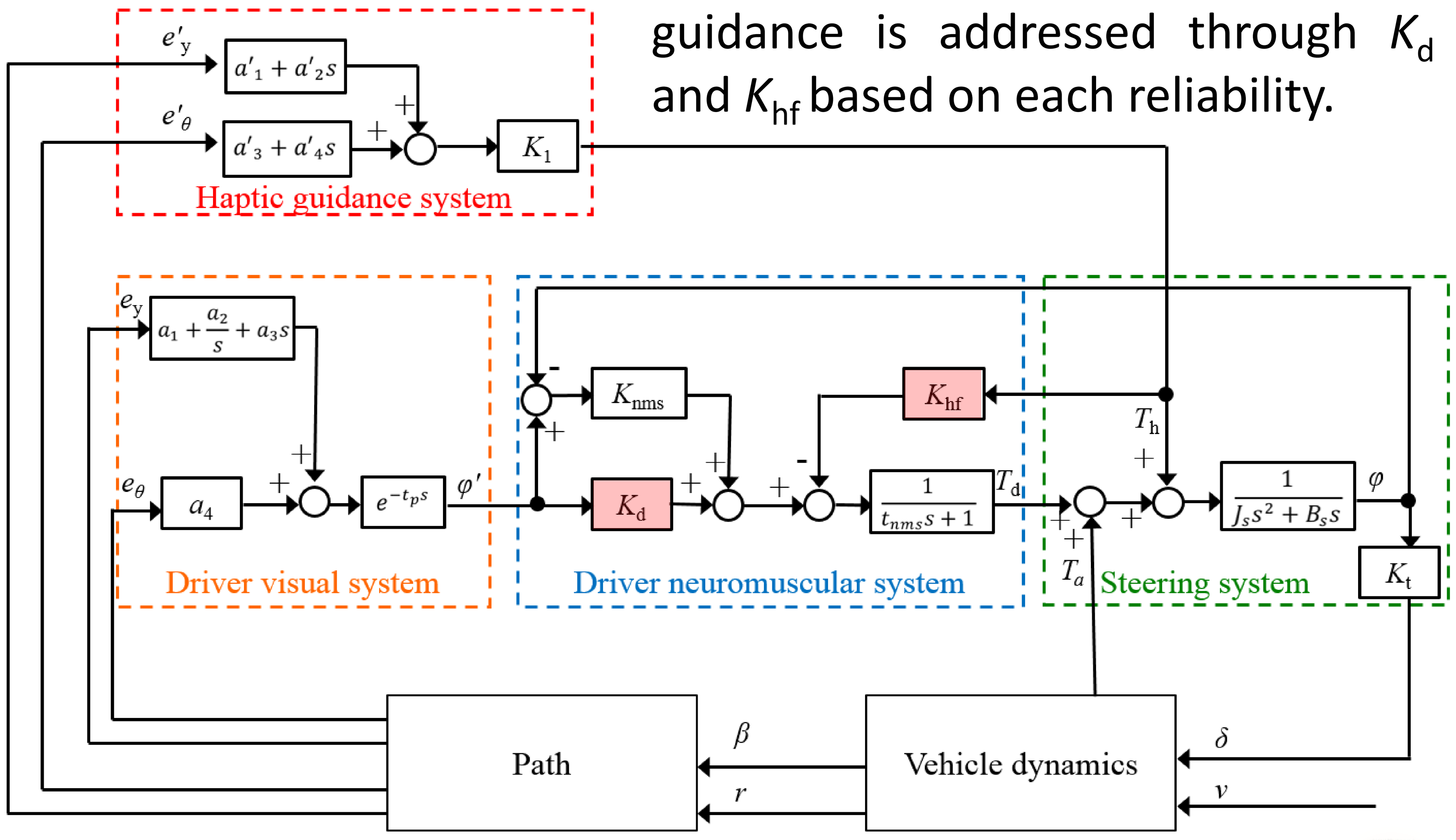
Introduction

Understanding of driver behavior based on measurements and modeling is crucial to design and evaluation of driver-automation shared control system. Our aim is to propose a driver model with integration of visual guidance from road ahead and haptic guidance from a steering system. It is hypothesized that a driver relies on visual and haptic guidance through a weighting process.

Driver-automation shared control



The driver model for shared control in a lane following task consists of a visual system and a neuromuscular system.



The integration of visual and haptic guidance is addressed through K_d and K_{hf} based on each reliability.

Model identification and validation

The data recorded from a driving simulator experiment with 14 participants were used for driver model identification, including vehicle trajectory, T_h, T_d, and φ.

Driving environment

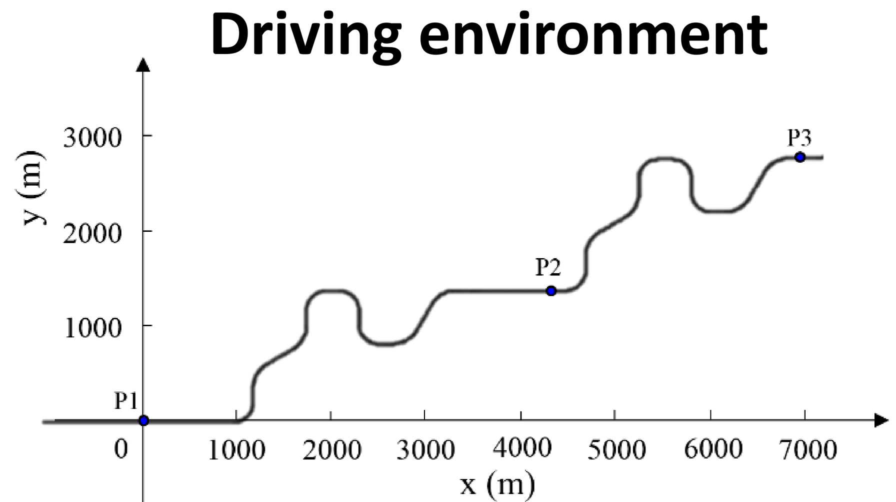
Input: $e_y, e_\theta, \varphi, T_h$

Output: T_d, φ'

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}0 & 0 & 0\\ a_2\frac{2}{t_p} & -\frac{2}{t_p} & 0\\ -a_2\frac{K_d+K_{nms}}{t_{nms}} & \frac{2(K_d+K_{nms})}{t_{nms}} & -\frac{1}{t_{nms}}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

$$+\begin{bmatrix}1 & 0 & 0 & 0\\ a_1\frac{2}{t_p} & a_4\frac{2}{t_p} & 0 & 0\\ -a_1\frac{K_d+K_{nms}}{t_{nms}} & -a_4\frac{K_d+K_{nms}}{t_{nms}} & -\frac{K_{nms}}{t_{nms}} & \frac{-K_{hf}}{t_{nms}}\end{bmatrix}\begin{bmatrix}e_y\\ e_\theta\\ \varphi\\ T_h\end{bmatrix}$$

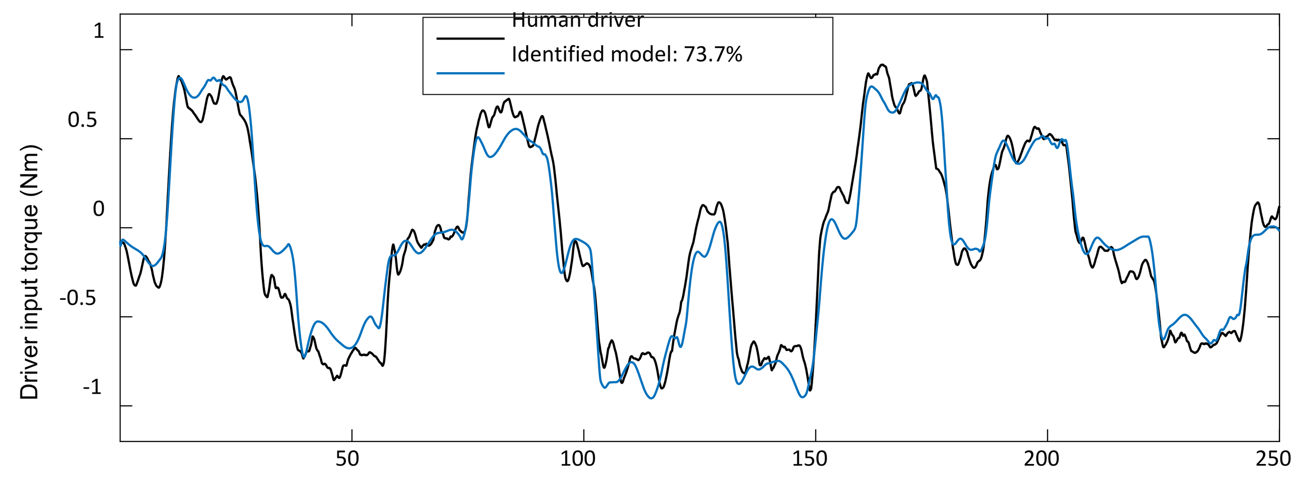
$$\begin{bmatrix}T_d\\ \varphi'\end{bmatrix}=\begin{bmatrix}0 & 0 & 1\\ -a_2 & 2 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0 & 0 & 0 & 0\\ -a_1 & -a_3 & 0 & 0\end{bmatrix}\begin{bmatrix}e_y\\ e_\theta\\ \varphi\\ T_h\end{bmatrix}$$



Driving course

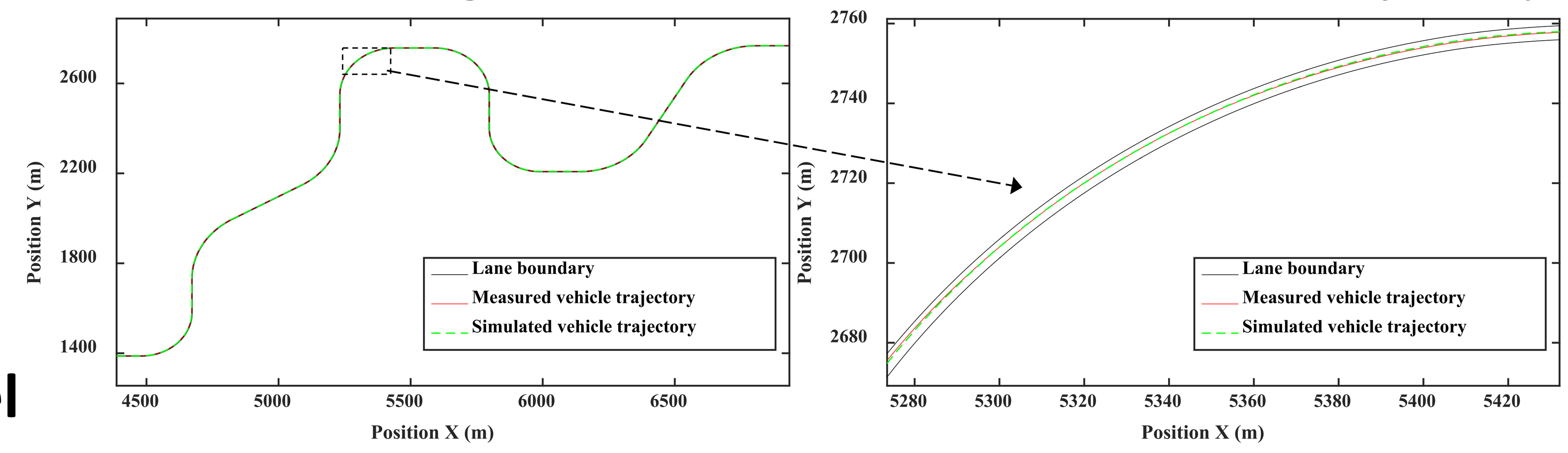
State-space realization of driver model

The proposed model matches driver input torque T_d with a fitness of 69% on average among participants.



Example of driver torque T_d fitting under shared control.

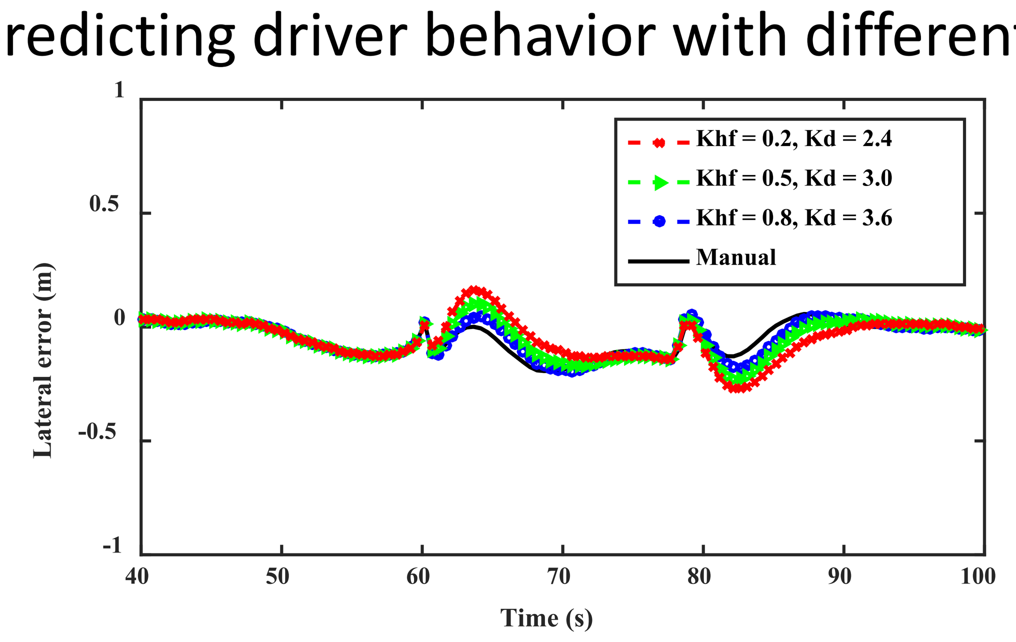
The validation results show that the simulated trajectory well followed the driving course and matched the measured trajectory.



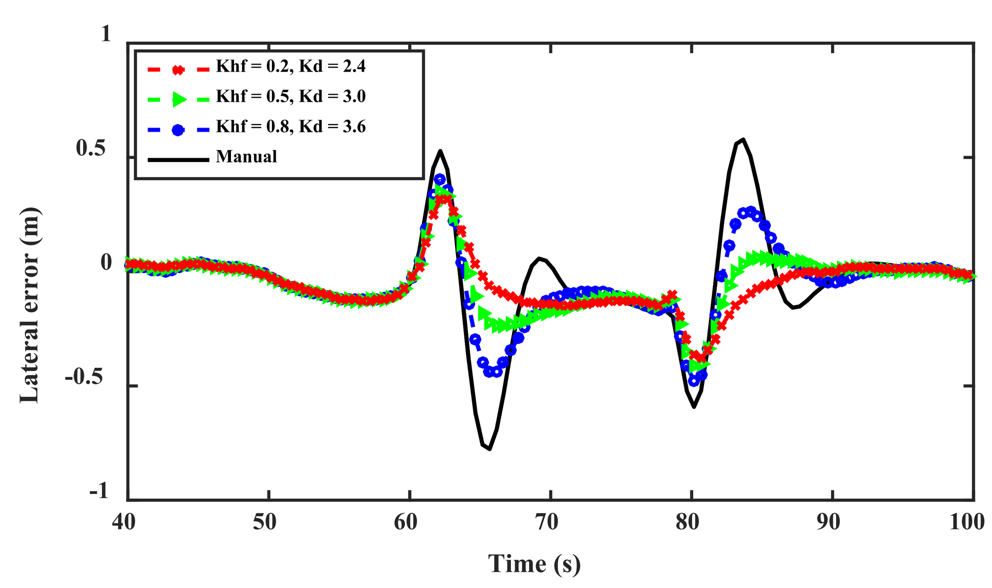
Example of comparison in vehicle trajectory

Case study

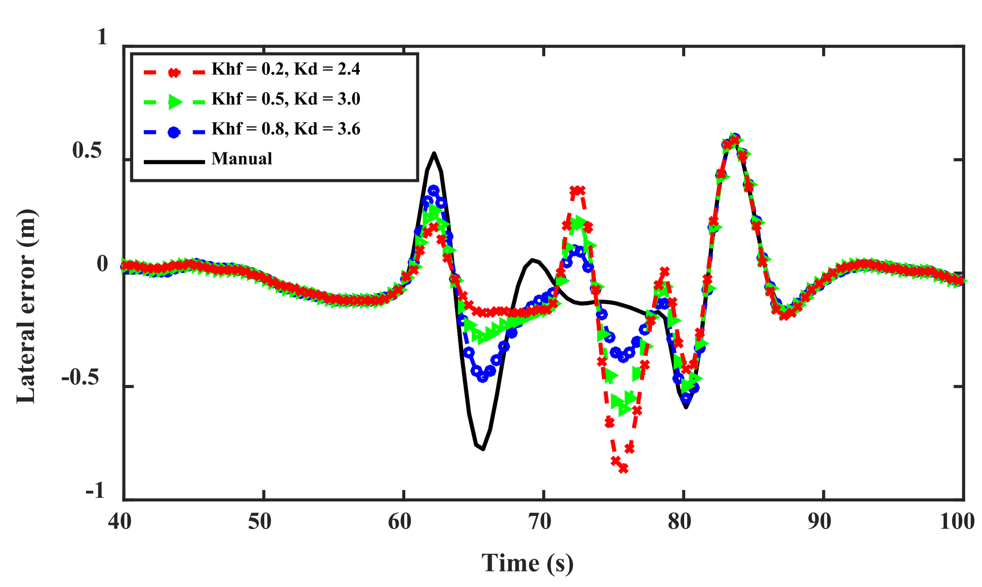
The case study by numerical simulation suggests that the parameterized driver model, especially with K_d and K_{hf}, is capable of predicting driver behavior with different driver attentiveness and in the case of a system failure.



t_p = 0.1 , without system failure



t_p = 0.5 , without system failure



t_p = 0.5 , with system failure

Publications

Zheng Wang, Tsutomu Kaizuka, and Kimihiko Nakano, "Effect of Haptic Guidance Steering on Lane Following Performance by Taking Account of Driver Reliance on the Assistance System". *Proc. IEEE Int. Conf. on Systems, Man, and Cybernetics*, Miyazaki, Japan, Oct. 2018, pp. 2717-2723.

Zheng Wang, Rencheng Zheng, Tsutomu Kaizuka, and Kimihiko Nakano, "Relationship between Gaze Behavior and Steering Performance for Driver–Automation Shared Control: A Driving Simulator Study," *IEEE Transactions on Intelligent Vehicles*, vol.4, no. 1, pp. 154-166, Mar. 2019.