

# Driver Model for Shared Control

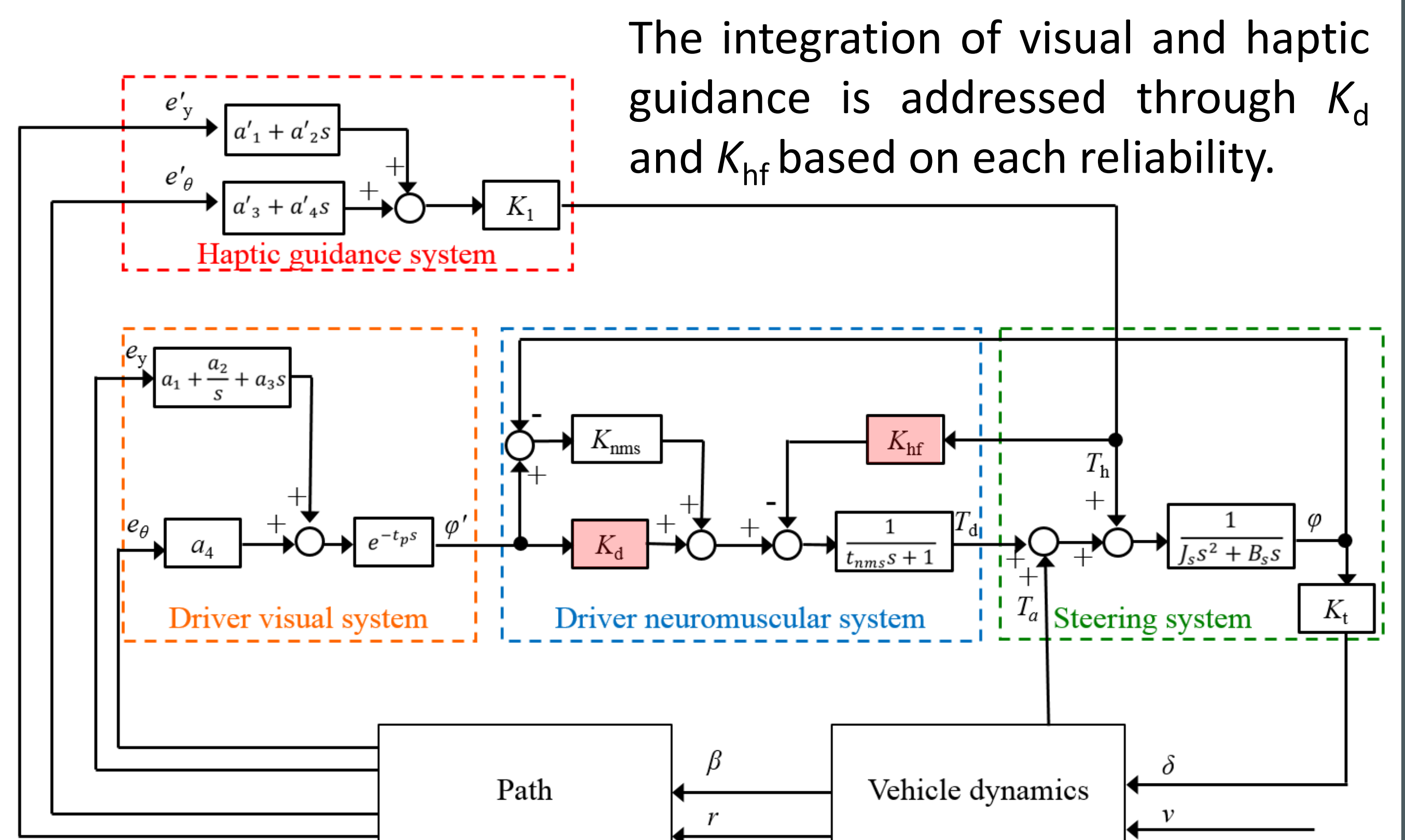
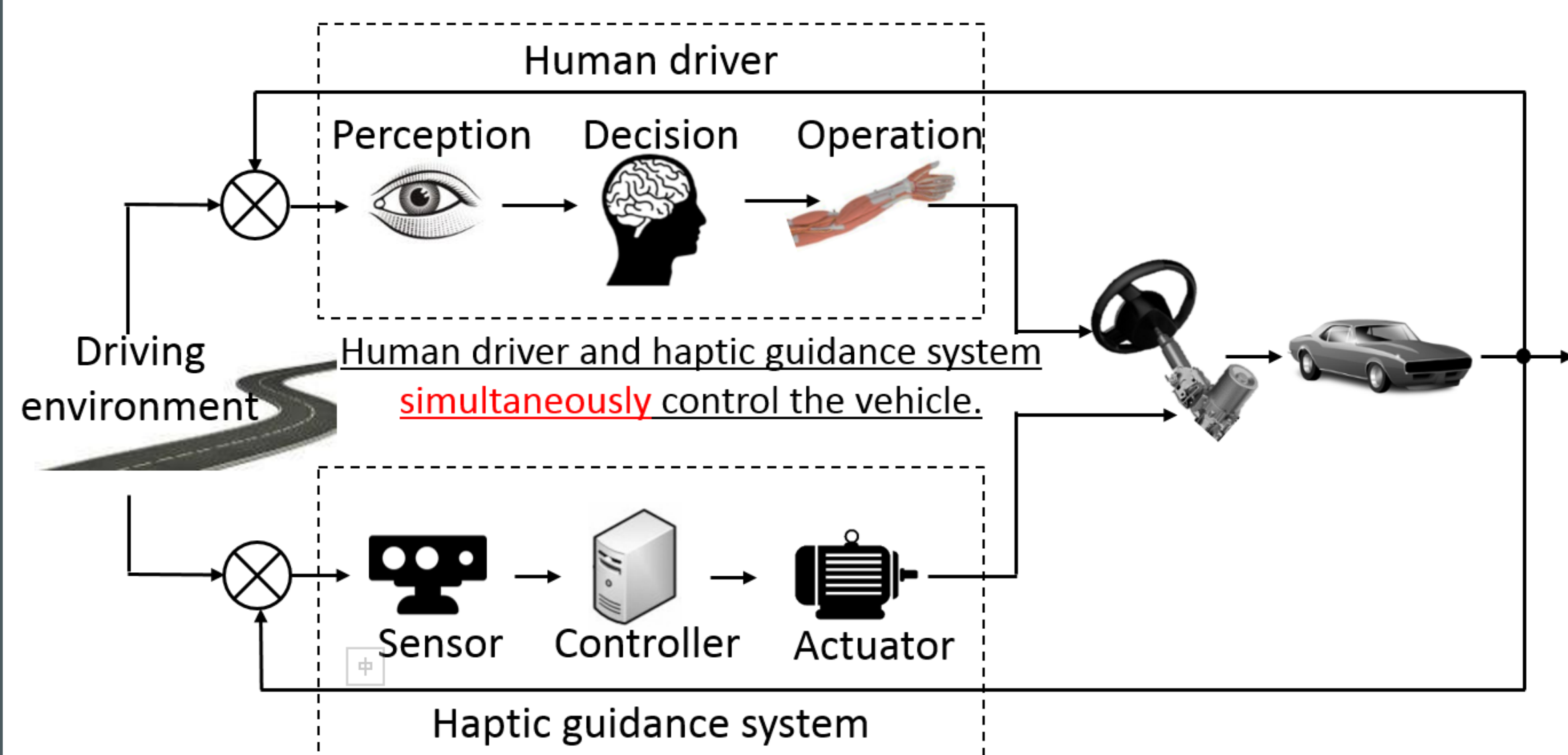
Partner: JTEKT Corporation

Fund: Grant-in-Aid for Scientific Research

## 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.

## Model identification and validation

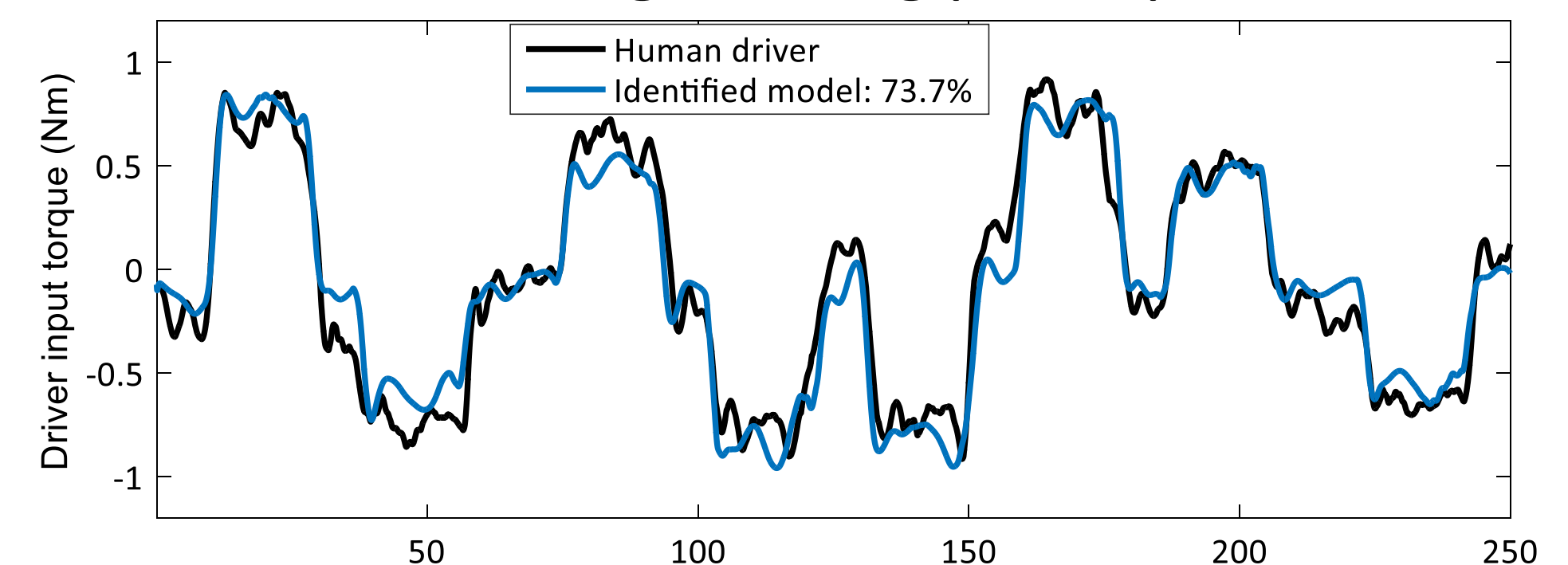
The data recorded from a driving simulator experiment with 14 participants were used for driver model identification, including vehicle trajectory,  $T_h$ ,  $T_d$ , and  $\varphi$ .



Input:  $e_y, e_\theta, \varphi, T_h$   
Output:  $T_d, \varphi'$

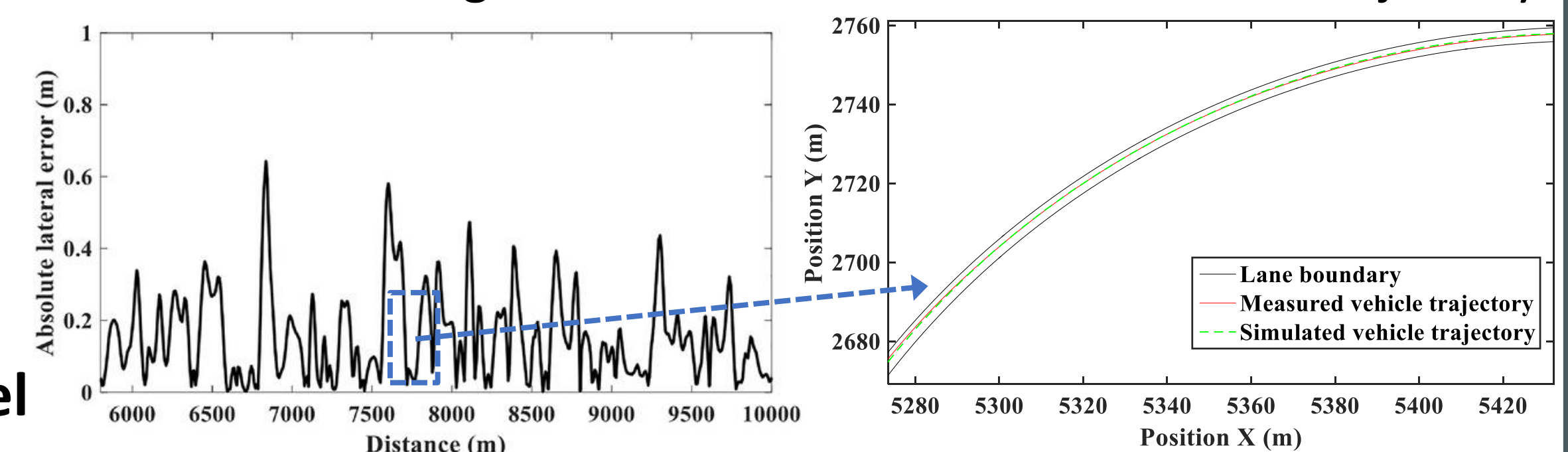
$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & \frac{2}{t_p} & 0 \\ a_1 & \frac{2}{t_p} & 0 \\ -a_2 & \frac{K_d + K_{nms}}{t_{nms}} & \frac{2(K_d + K_{nms})}{t_{nms}} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{t_{nms}} \end{bmatrix} \begin{bmatrix} e_y \\ e_\theta \\ T_h \end{bmatrix}$$

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.

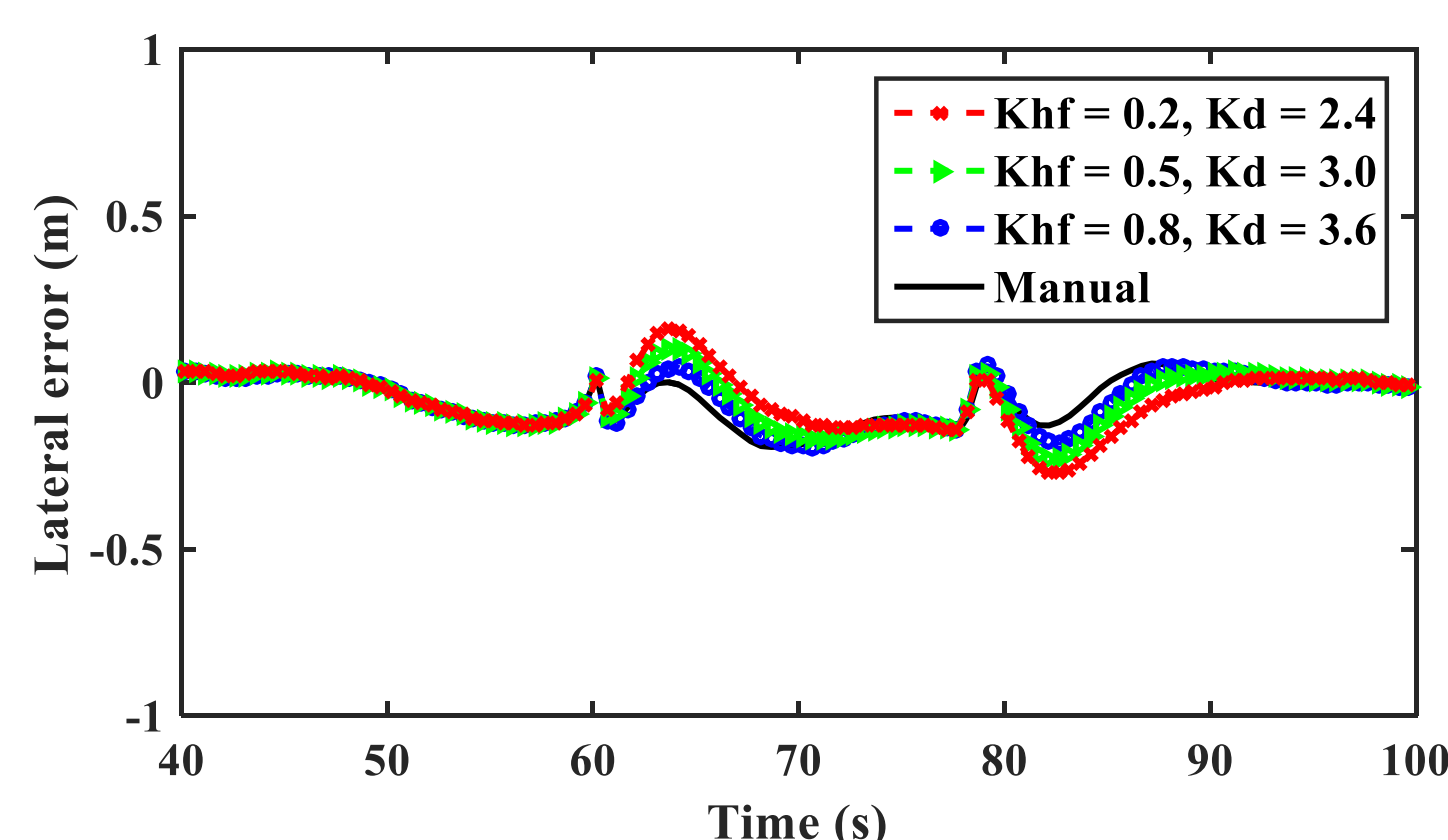
The validation results show that the simulated trajectory well followed the driving course and matched the measured trajectory.



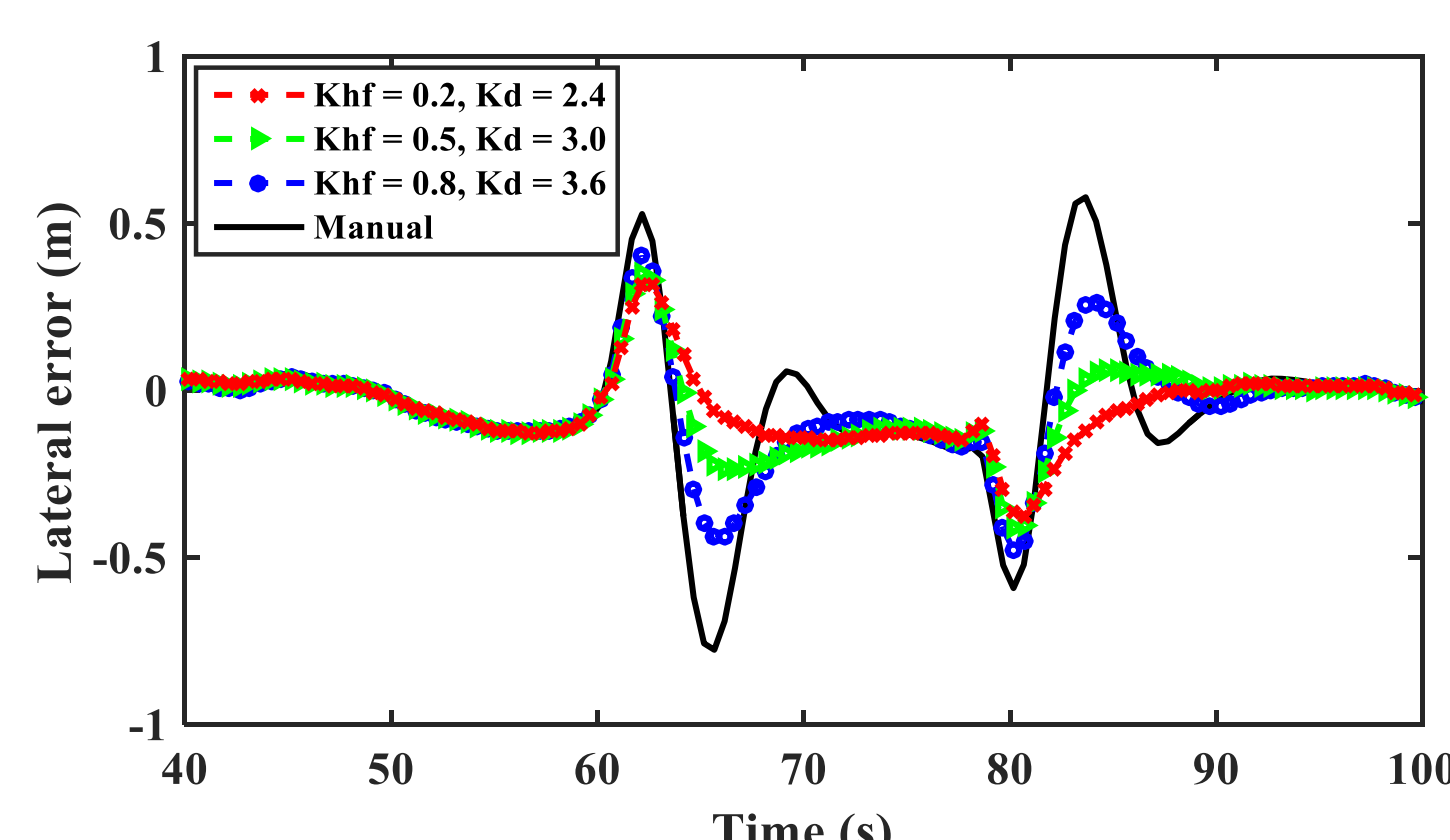
Example of comparison in vehicle trajectory

## Case study

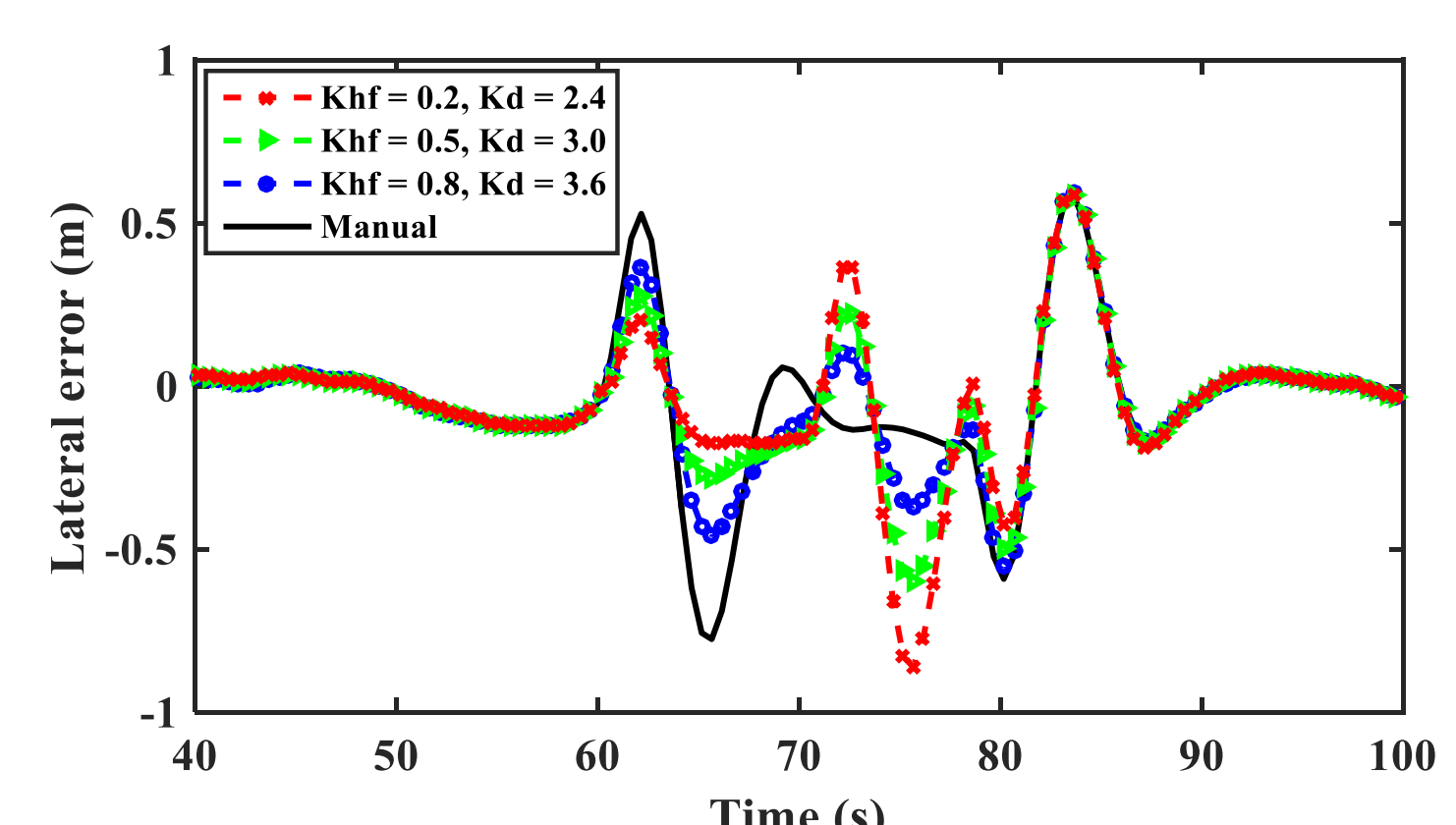
The case study by numerical simulation suggests that the parameterized driver model, especially with  $K_d$  and  $K_{hf}$ , is capable of predicting driver behavior with different driver attentiveness and in the case of a system failure, as similar results were observed from experimental studies.



$t_p = 0.1$ , without system failure



$t_p = 0.5$ , without system failure



$t_p = 0.5$ , with system failure

## Publications

Wang Z., Zheng R., Nacpil E.J.C., Nakano K., 2022, Modeling and analysis of driver behaviour under shared control through weighted visual and haptic guidance, *IET Intelligent Transport Systems*, vol. 16, no. 5, pp. 648-660.

Wang Z., Zheng R., Kaizuka T., Nakano K., 2019, 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.