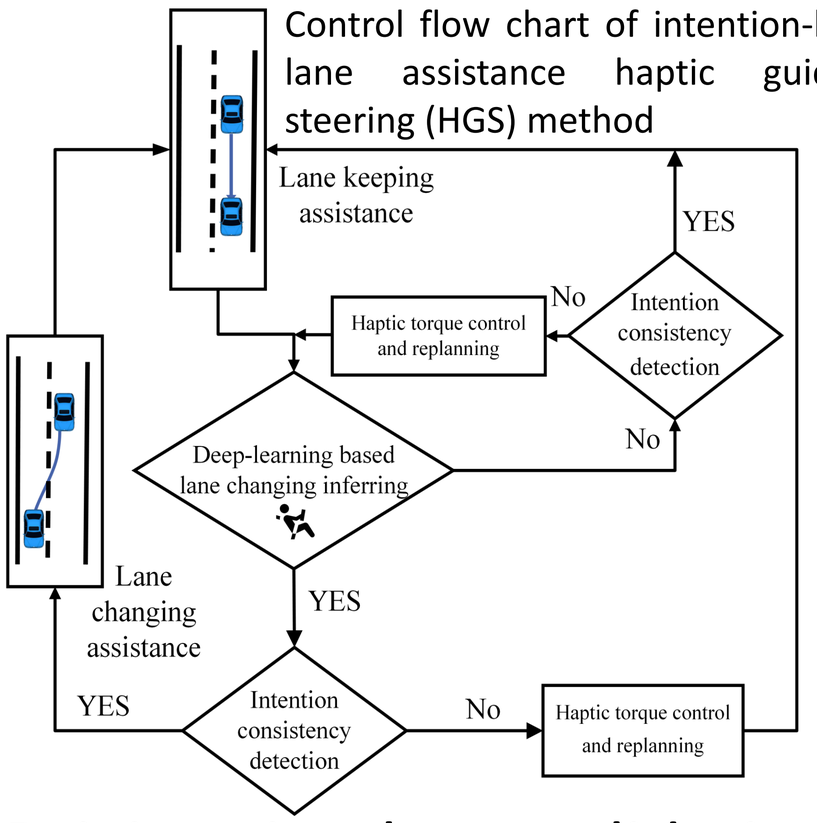
Intention-Based Lane Changing and Lane Keeping Haptic Guidance Steering System

Introduction

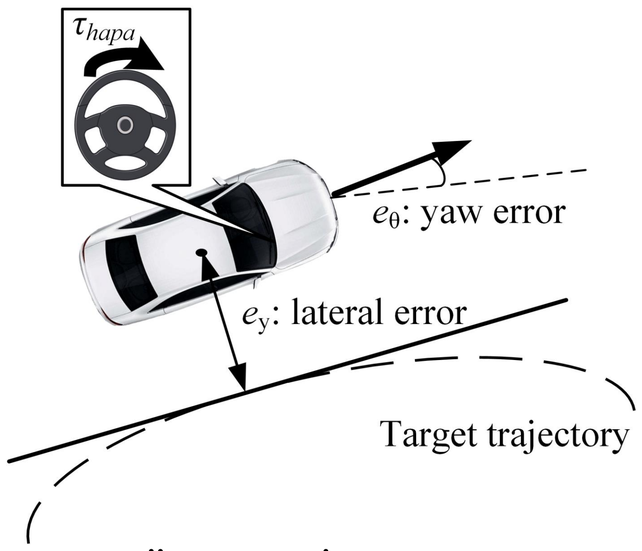
This study explored a new haptic steering interaction method, including the design and evaluation of an Intention-Based Haptic Steering (IBHS) system. Such an intention-based method can support both lane keeping and lane changing assistance, by detecting a driver's Lane Change (LC) intention. A driving simulator experiment demonstrated that the supporting system decreased the lane departure risk in the lane keeping tasks and could support a fast and stable lane changing maneuver.

Intention-based lane assistance haptic steering system

Control flow chart of intention-based lane assistance haptic guidance steering (HGS) method



single preview-point method for controlling haptic guidance torque

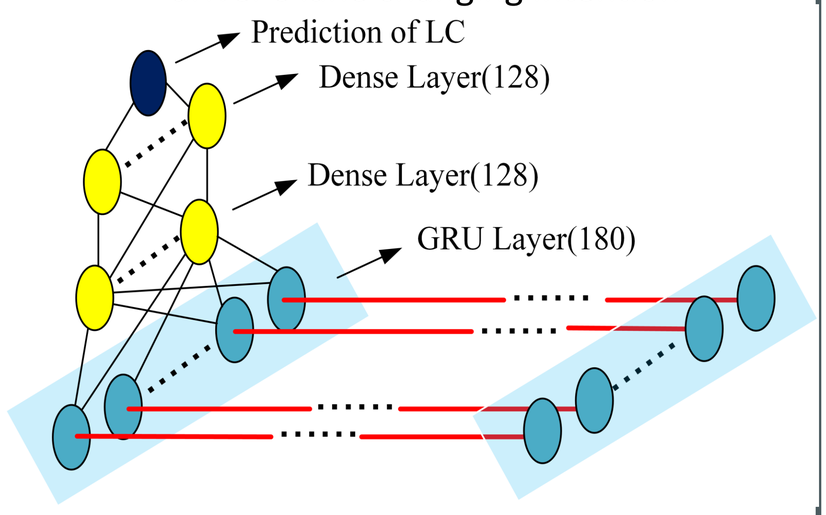


$$\tau_{hapi} = J_{eq}\ddot{\vartheta}_{sw} + B_{eq}\dot{\vartheta}_{sw} + K_{Fz}\vartheta_{sw} - \tau_{dr}' + \tau_{dis}$$

$$\tau_{dr}' = K_y e_y + K_{yd}\dot{e}_\vartheta + K_\vartheta \vartheta_{sw} + K_\alpha \alpha$$

$$\tau_{hapa} = K_h \tau_{hapi}$$

Unrolled GRU layer with 180 units, the top layer gives the prediction of driver's lane changing intention

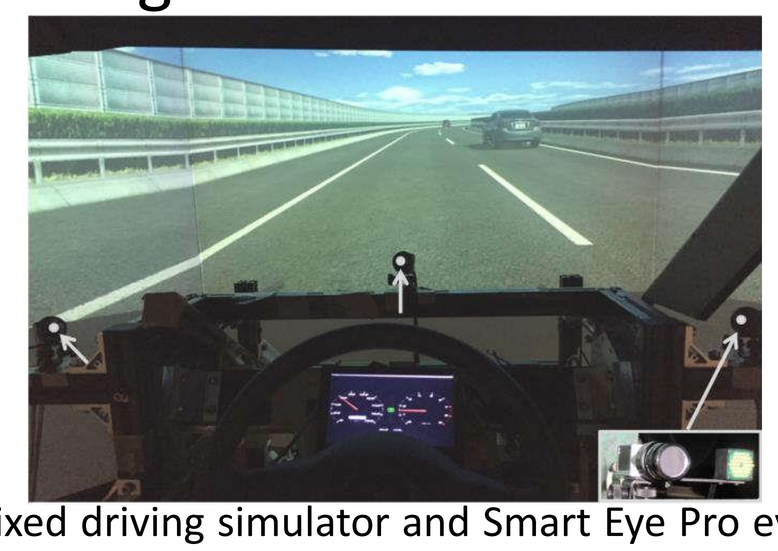


Hidden state: $h_t^j = (1-z_t^j)h_{t-1}^j + z_t^j \tilde{h}_t^j$

Update gate: $z_t^j = \sigma(W_z \mathbf{x}_t + U_z \mathbf{h}_{t-1})^j$

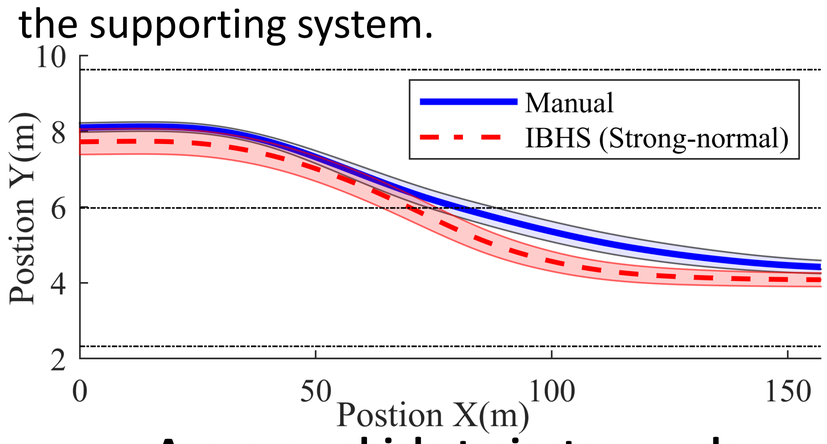
- **New memory:** $\tilde{h}_t^j = \tanh(W_z \mathbf{x}_t + U(\mathbf{r}_t \odot \mathbf{h}_{t-1}))^j$
- **Reset gate:** $r_t^j = \sigma(W_r \mathbf{x}_t + U_r \mathbf{h}_{t-1})^j$

Driving simulator validation

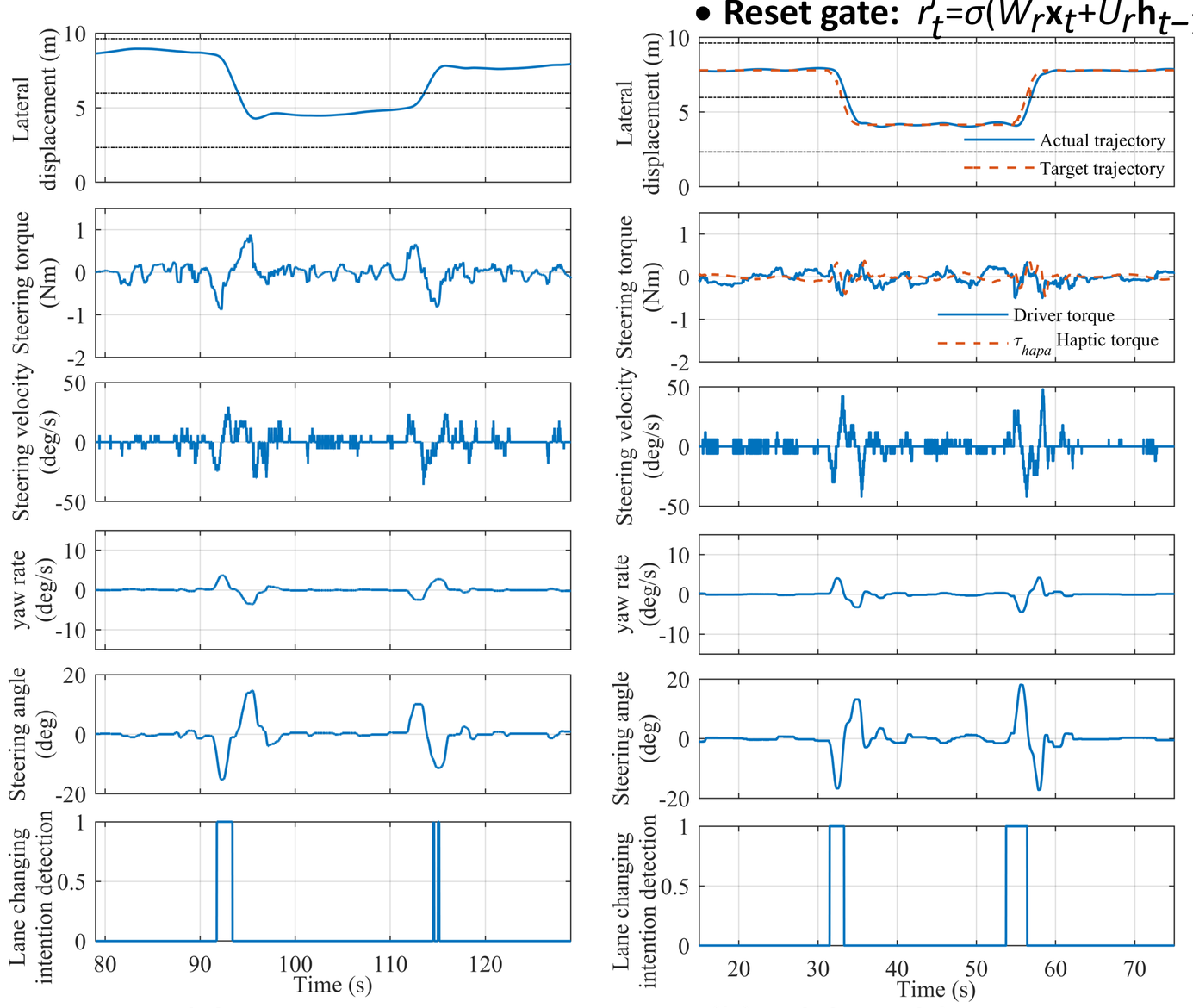


Fixed driving simulator and Smart Eye Pro eye tracking system.

A driving simulator experiment with 12 participants was conducted to demonstrate the supporting system.



Average vehicle trajectory under Manual and IBHS conditions



(a) Manual driving **(b) Driving with IBHS system**

Overall performance under Manual and IBHS conditions

Conclusion

1. The IBHS was effective in lowing lane departure risk, and showed a tendency to reduce the overshoot distance
2. A strong supporting torque showed better assistive performance than a weak torque when driving with IBHS assistance.
3. The intention consistency detection method could accurately catch the driver's intention and achieve smooth re-planning.

Publications

Yan Z., Yang K., Wang Z., Yang B.,Kaizuka T. ,Nakano K., 2021, "Intention-Based Lane Changing and Lane Keeping Haptic Guidance Steering System," *IEEE Trans. Intell. Veh.*, vol. 6, no. 4, pp. 622–633,

Yan Z., Yang K., Wang Z., Yang B.,Kaizuka T. ,Nakano K., 2019, "Time to lane change and completion prediction based on Gated Recurrent Unit Network," in *IEEE Intelligent Vehicles Symposium, Proceedings*, vol. 2019-June, pp. 102–107