

Proposal of a Steering Assist System Considering Individual Driver Input Constraints

Third Report: Actual Vehicle Evaluation with Drivers Simulating Physical Constraints

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Introduction: Population aging increases the importance of personal mobility for people with physical limitations. Hemiparesis may require one-handed steering, restricting steering range and fine adjustment and potentially reducing vehicle-control accuracy. This study leaves strategic and tactical decisions to the driver, compensates reduced input capability, and shares machine vehicle-control skill while building on driver steering. The system separates MFC-based response adaptation for restoring effective driver control authority from reference-input mixing for supplying machine-side skill. A previous VR driving-simulator study revealed changes in vehicle metrics and steering feel that required balancing; this study examines whether those trends persist in a real vehicle.

System and Evaluation: The steer-by-wire system integrates two separately designed functions (Fig. 1). Execution-level model-following control (MFC) shapes yaw response for limited driver input. Operational-level reference-input mixing shares path-following skill from a nonlinear model-predictive reference driver, with shared ratio α setting the reference-input amount. To isolate α , the same MFC reference yaw response was used for all conditions. For safety and repeatability, three drivers in their 30s with comparable driving skill were selected. They completed two closed-course runs under one- and two-handed conditions at $\alpha = 0, 0.1, 0.2$, and 0.4 ; in one-handed trials, one arm was restrained. Straight and 50-m-radius curve (R50) sections were analyzed separately using standard deviations of within-segment lateral position and yaw-rate tracking error; lateral-position RMSE and steering entropy were also evaluated. Ethics approval and written informed consent were obtained.

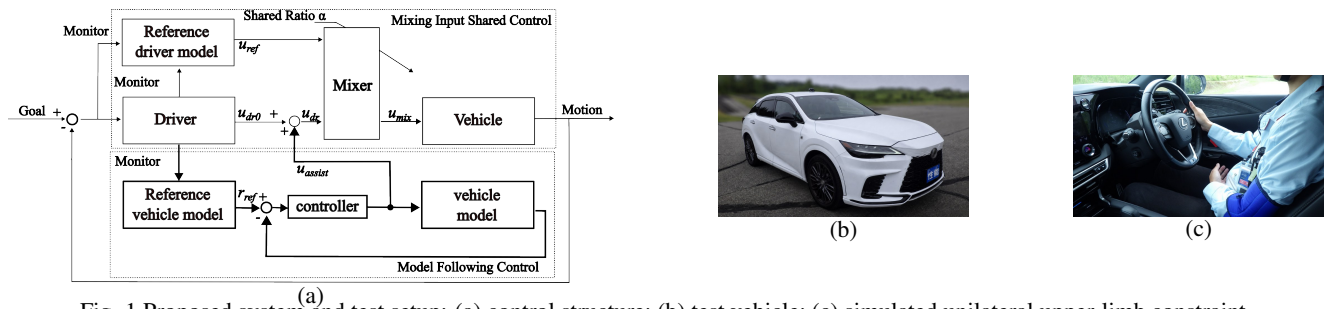


Fig. 1 Proposed system and test setup: (a) control structure; (b) test vehicle; (c) simulated unilateral upper-limb constraint.

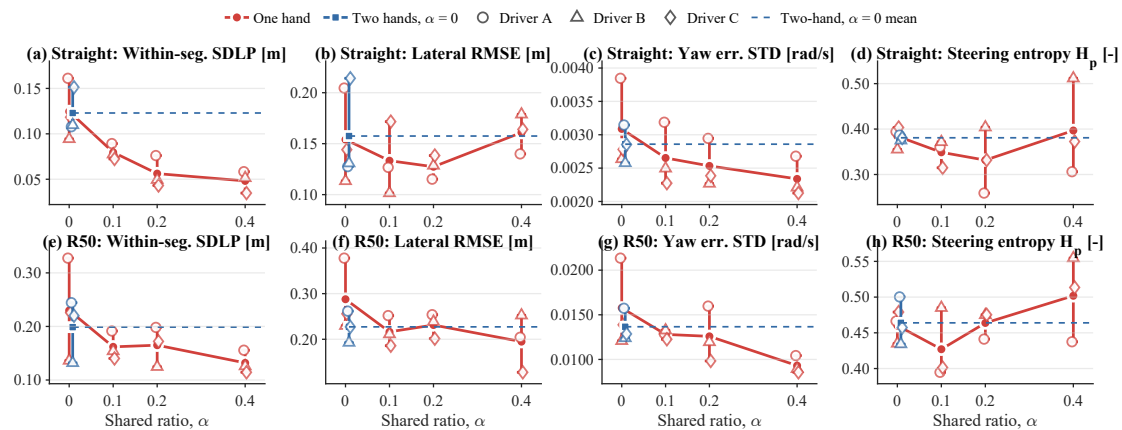


Fig. 2 Real-vehicle results for the straight and R50 sections ($n = 3$; two runs pooled per driver; dashed lines show the mean two-handed $\alpha = 0$ values).

Results and Discussion: At one-handed $\alpha = 0.4$, both primary standard deviations were lower than at one-handed $\alpha = 0$ for all drivers in both sections (Fig. 2); their R50 means decreased by 42.6% and 41.0%. Both measures for every driver were also no higher than each driver's own two-handed $\alpha = 0$ value, consistent in direction with the previous VR trend. However, lateral-position RMSE increased by 9.9% for one driver in R50 and for two drivers on the straight. Because driver input remained after mixing, variation could decrease while reference-path offset remained. R50 steering entropy increased by 9.1% on average at $\alpha = 0.4$. In informal interviews, all drivers preferred $\alpha = 0.2$, suggesting a trade-off between vehicle-side accuracy and steering feel.

Conclusion: With the MFC reference yaw response fixed, increasing the shared ratio reduced local lateral-position variation and yaw-rate tracking error during simulated one-handed steering, extending the previous VR trend to a real vehicle. RMSE, steering entropy, and preference indicate that ratio design should address both vehicle-side accuracy and steering feel. Generalizability and MFC range compensation require evaluation with physically constrained drivers.