Haptics research for PAVs

Max Planck Institute for Biological Cybernetics

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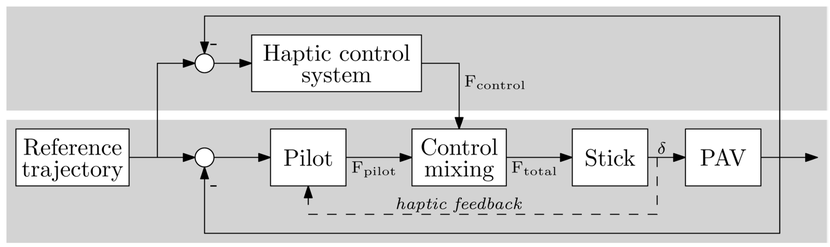
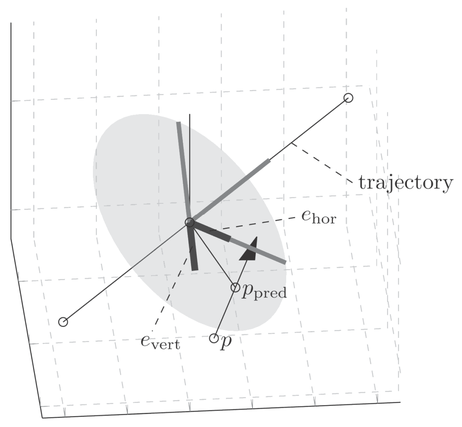
Haptic shared control and Highway-in-the-Sky displays

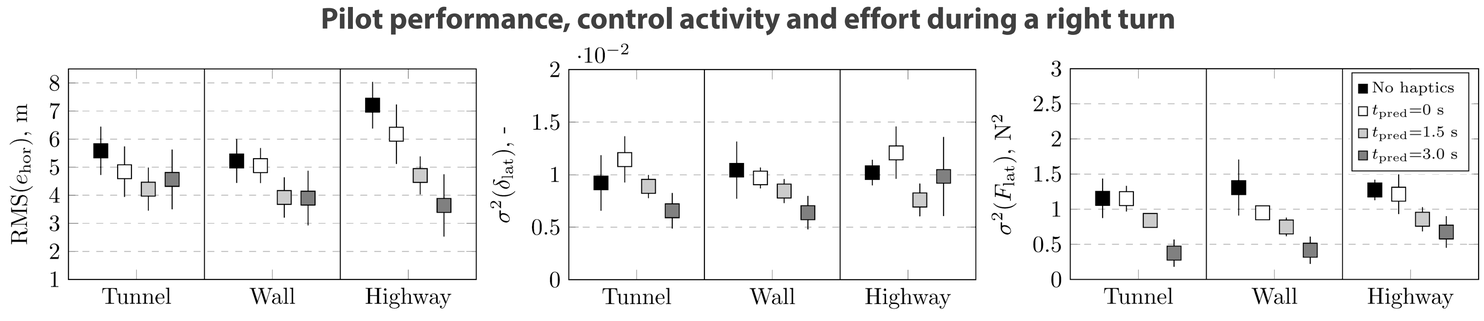
Haptic shared control systems allow pilots to continuously share control authority with an automatic control system through force interactions on a control stick. By combining such a system with a HITS display, a pilot can be guided along the flight trajectory.





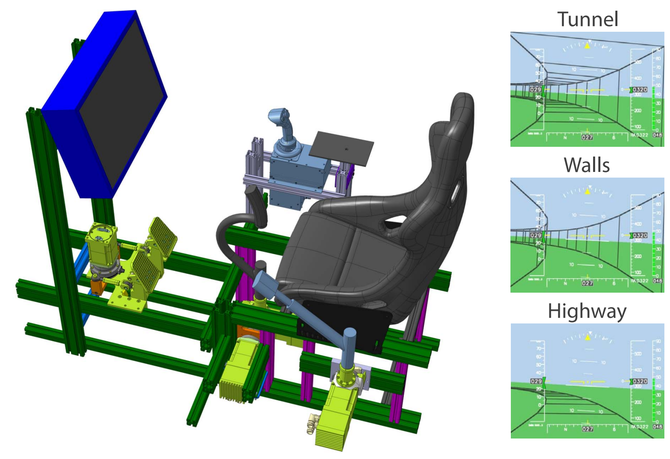
Haptic guidance cues allow pilots to achieve better performance (lower error) with lower control activity. However, pilots increase their control effort when the haptic guidance cues are based on an instantaneous error instead of the predicted error of the position of the PAV with respect to the flight trajectory. A tunnel and a wall representation of the flight trajectory lead to best performance (lowest error), whereas a highway representation results in worse performance and higher control activity and effort. **The combination of a haptic shared control framework and HITS display can provide pilots with limited flight experience with an easy-to-use control interface for PAVs.**

Pilot performance, control activity and effort during a right turn



Experimental setup

We use a fixed-base simulator with a control loaded sidestick, cyclic, collective and pedals, and a HITS display with various configurations

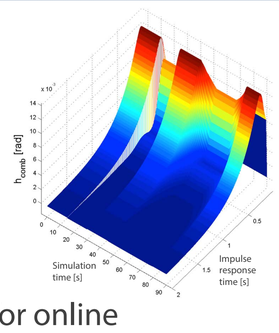


Selected publications

1. Nieuwenhuizen F. M. and Bülthoff H. H. (2014) **Evaluation of Haptic Shared Control and a Highway-in-the-Sky Display for Personal Aerial Vehicles** *AIAA Modeling and Simulation Technologies Conference 2014: held at the SciTech Forum 2014*, AIAA-2014-0808, 1-9.
2. Olivari M., Nieuwenhuizen F. M., Bülthoff H. H. and Pollini L. (2014) **Pilot Adaptation to Different Classes of Haptic Aids in Tracking Tasks** *Journal of Guidance, Control, and Dynamics* **37(6)** 1741-1753.
3. Olivari M., Nieuwenhuizen F. M., Bülthoff H. H. and Pollini L. (2014) **Identifying Time-Varying Neuromuscular System with a Recursive Least-Squares Algorithm: a Monte-Carlo Simulation Study** *IEEE International Conference on Systems, Man, and Cybernetics (SMC 2014)*, 1-6.

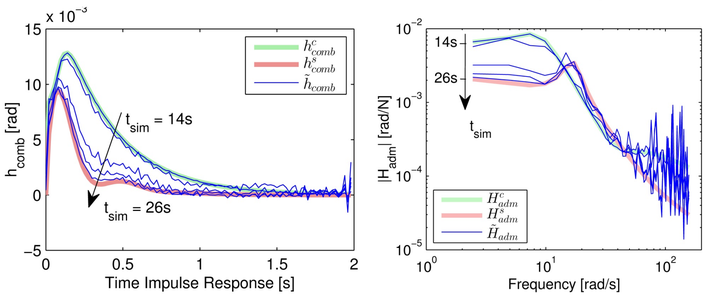
Real-time admittance

In realistic scenarios, admittance in response to haptic aids varies continuously dependent on many factors



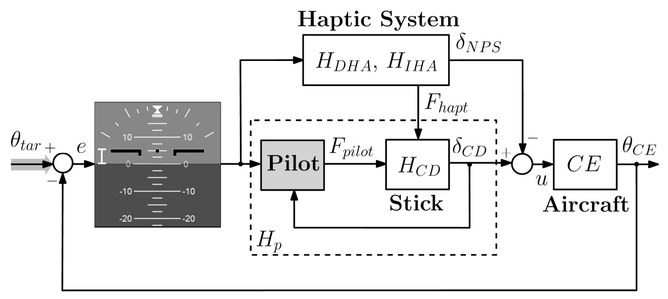
We have developed methods for online estimating time-varying neuromuscular dynamics during force-related tasks. Even with high level of remnant noise, the algorithm provided accurate estimates when neuromuscular dynamics changed slowly.

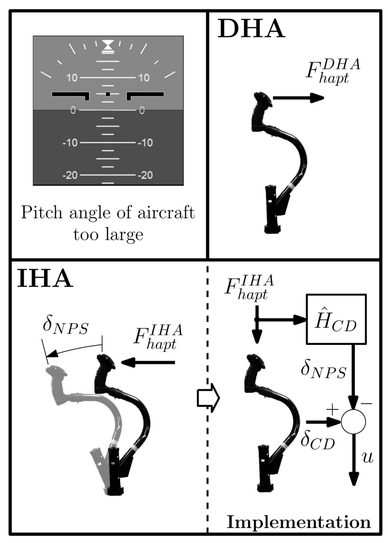
Estimates after an instantaneous change



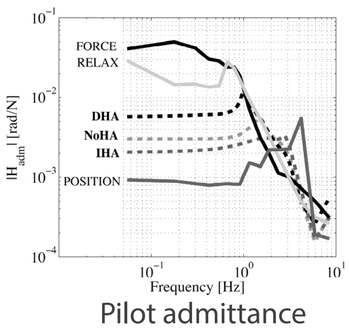
Identification of pilot behaviour with haptic aids

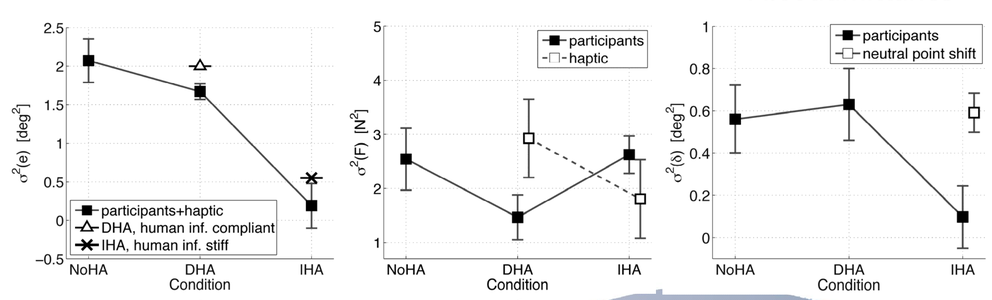
Analytical designs of haptic aids require adequate knowledge about changes in pilot behaviour. We use system identification techniques to determine how pilots adapt their visual response and the biomechanical properties of their arm (admittance) to haptic aids.





In general, haptic aids improve control performance and cause pilots to significantly adapt their admittance and visual response to fully exploit the available cues.





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