The control of an aerial vehicle is a complex task that requires a pilot’s continuous attention. Haptic aids can be used to help pilots during the manual control task. Haptic aids provide tactile sensations through a continuous external force applied to the control device. The design of the haptic force becomes a crucial issue, since it has to represent information that pilots can easily exploit. The aim of the PhD project is to design the haptic force based on the effect it has on the human dynamic responses (human-centered design).

**INTRODUCTION**

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**MULTI-LOOP PILOT IDENTIFICATION [1, 2]**

To identify pilot visual (VIS) and neuromuscular (ADM) responses, multi-loop identification techniques are needed. The conventional identification technique was proved to provide biased estimates. Two novel methods were proposed that do not show the same limitation of the conventional method.

- **CSD-ML METHOD**
  \[ H_{\text{tar}} = \frac{s_{\text{tar}}}{s_{\text{tar}} s_{\text{dist}}} \]
  \[ H_{\text{dist}} = \frac{s_{\text{dist}}}{s_{\text{dist}} s_{\text{dist}}} \]

- **ARX METHOD**
  \[ \delta_C = H_c e + H_{\text{dist}} F_{\text{dist}} + H_n n \]

**DHA VS IHA [1, 3]**

Two different approach were investigated to design the haptic aid:

- the Direct Haptic Aid (DHA), which produces tactile sensations that suggest the right control action to pilots. This was achieved by designing the DHA as a standard compensator that regulates \( e \) to zero.
- the Indirect Haptic Aid (IHA), which informs pilots and increases situational awareness indirectly. The IHA was designed to provide a force opposite in sign with respect to the DHA. Furthermore, the neutral point of the control device was shifted so that the actual command to the aircraft was zero with pilot out-of-the-loop.

**EXPERIMENTAL RESULTS**

- **CONTROL EFFORT:**
  - Lower with DHA.
  - Lower with IHA.

- **PERFORMANCE:**
  - Better with HAPT and AUT in a similar way.
  - Better with HAPT and AUT. AUT outperforms NoAID and HAPT.
  - Higher crossover frequency \( f_c \) with AUT. Lower neuromuscular peak with HAPT.

**PUBLICATIONS**