Visitor Research Report

Visitor Name:	**Mr. Mark van der Steen** **Delft University of Technology** **The Netherlands**
Area of Research:	**Operator State Estimation and Management through Haptic-Multimodal Interaction**
Period of Visit:	**February 9, 2009 – May 29, 2009**

Goal:
Haptic control interfaces are systems that provide the pilot/operator with feedback about the underlying controller's actions through forces or displacements on the stick. For example, the autopilot can relay it's actions on the control stick of an aircraft, leaving the pilot with both a sense of what is actually going on after he dialed in the desired route and the ability to override the suggested actions by simply applying his own forces on the stick. In other terms, the pilot is now aware of what the automation is doing.

However, de automation is still not aware of what the pilot is doing in high level terms. Although the control inputs themselves are readily available, the automation is not aware of the pilot's intentions or state. Is the pilot actually happy with the provided feedback? Does the pilot want to stay on this route? Is the pilot stressed or overworked? The intent of the haptic state estimator (HSE) is to use the same hardware required for a haptic control system to try and answer these questions.

Strategy:
Control actions can be analyzed in many different ways. These methods can generally be separated in time and frequency domain methods, respectively looking at input histories and their frequency content. The HSE is planned to use both, but before the HSE itself can be constructed, it is necessary to find the indicators for stress, high workload or the desire to reduce the support. For that purpose, an experiment was setup that had to excite these different modes of operation.

The experiment consists of a simple flying task in which the pilot merely has to control the roll mode of a simulated business aircraft and where vertical motion is restrained. The pilot had to alternatively fly along the supported route and away from it, so as to excite both path following and path leaving behavior. Furthermore, an additional task was added in various intensities to excite various levels of stress and/or workload.

During these flying tasks, a force on the stick was added using specifically designed signals at selected frequencies. By measuring the reaction to these particular frequencies, it is possible to build a frequency domain estimate of the pilot-stick system. Since the

characteristics of the stick are well known, it is now possible to determine the frequency response function of the pilot's admittance, which is (simply said) the degree to which the pilot allows stick disturbances to show up in his own control inputs. At low frequencies the pilot is able to manipulate this throughput consciously, but at higher frequencies (roughly beyond 1 Hz), the response will only show unconscious characteristics. These include reflex characteristics and grip strength, the latter of which seems to be a good indicator for a desire to leave the guided path.

In time domain, it is possible to determine how well a pilot performed on both tasks by looking at RMS errors. Furthermore, standard deviations of the stick position and applied force give an idea of how comfortable or consistent the pilot acted, which can serve as an indicator for high stress or workload.

To gain more confidence on the assumed workload, several physiological measurements were taken on the subjects, namely an electrocardiogram (ECG), galvanic skin response (GSR) and pupil diameter. From the ECG it is possible to extract heart rate, beat-to-beat interval and heart rate variability (HRV), the latter of which is in fact a frequency domain result showing the power of heart rate changes at selected frequencies.

Accomplishments:
So far, data has been collected on a number of subjects and the first analysis methods have been written. These show that some of the hypothesis are correct and there is potential for a functional HSE, but it is to early to give a definitive answer on that. One of the most interesting and at the same time unsettling realizations is that both the desire to leave a guided path and a high workload show similar results in many parameters and potential indicators, making it difficult to reliably distinguish between them. On the other hand, the experiment has shown that it may not be needed to make this distinction, as both pilot states might require similar actions from the automation. This is however not yet fully clear and will be investigated in the future.

Future Work:
The future work will consist of further analysis and construction of (i.e. programming) a live HSE. This will largely take place over the following months as part of Mark van der Steen's master thesis and in close cooperation between NASA Langley and Delft University of Technology. The goal of the analysis is to refine the knowledge on the indicators that have been found so far and to find numerical correlations between these indicators and the exhibited behavior. Using this knowledge, a range of configurations for the HSE will be built and tested in a further experiment. The main focus will be on the pilot's desire to leave a guided path, yet attention will be spent on high workload cases for the reasons mentioned in the previous paragraph.

Pending Publications:
None yet

Seminar Presented:

On Friday May 29th 2009, Mark van der Steen has given ('will give' at the moment of writing) a talk at NASA Langley on the preliminary results and what the future may bring.