Using Eye-Tracking for Adaptive Human-Machine Interfaces for Pilots: A Literature Review and Sample Cases

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1. Introduction

The need for an adaptive interface that changes its layout and elements according to the needs of the pilots is critical in such a demanding human-machine interface (HMI), where a lot of information is processed rapidly by the pilots. We argue that the use of eye-tracking technologies can assist HMI in adapting to prevent human errors such as failing to see important information, misinterpreting data, or failing to act. In this paper, we present a literature review of the use of eye-tracking in adaptive HMI for various cases of pilots (flight simulators, drone pilots, cockpit pilots), and we discuss two sample cases demonstrating the potential of using eye-tracking technology in adaptive HMI for pilots.

2. Use of Eye-Tracking in Adaptive HMI for Pilots

2.1 Flight Simulator Games Pilots

The utilization of eye-tracking technology was envisioned at an early stage in the game industry, particularly in first-person shooter games, to assist players in maintaining precise aim even when the target is in motion [1], as well as in the concept design of the first flight simulators to adjust the player's visual perspective [2]. Modern eye tracking technology is incorporated in various games [3-5], including the MS Flight Simulator, where the use of gaze-based interactions enables the pilot to fly the plane keeping their hands in the controls, while providing extended view for the in-game camera and improved spatial awareness. Additionally, using eye-tracking data, players could be guided to relevant areas of the cockpit [6].

2.2 Unmanned Aerial Vehicle (UAV/Drone) Pilots

Most works for UAV pilots focus on using eye-tracking technology to provide better control of the drone for people in need [7] or to be used in the auxiliary control of UAVs, which have various effects in improving the efficiency and accuracy of UAV operation and reducing the cognitive load of the pilot [8, 9]. Similarly, eye-tracking could be used to monitor the performance of drone pilots and detect abnormal statuses even in cases of multi-UAV operators [10]. Following these works, the use of eye-tracking data could initiate changes in the HMI of the drone pilot application to help pilots to overcome difficult situations, adapt to new challenges, and focus on data they have failed to monitor in time.

2.3 Use of Eye Tracking in Aviation

Data from eye-tracking have the potential to provide direct measures of pilots' information processing in the cockpit, including the information that is sampled by the operator over a given period (e.g., the distribution of fixation locations), and the time that it takes to process this information (e.g., fixation durations) [11]. Additionally, the analysis of the pilots' gaze distribution is used to measure how the pilots' task load influence visual behavior and performance [12, 13] and, generally, understanding of how the pilot processes the information in the cockpit while carrying out particular tasks [14].

3. Sample Cases

This section presents two sample cases demonstrating the potential of using eye-tracking technology for adaptive HMI for pilots. The former took place on a UAV simulator (DJI Flight Simulator) using an eye-tracking screen (Tobii screen eye-tracker). The pilots' fixation points were used to identify reactions and needs for adaptation. Pilots used the actual UAV controller, and the interaction analysis focused on adapting to critical situations (e.g., flying fast at low altitudes and avoiding obstacles).

The latter was based on a UAV (DJI Mavic 2 Pro) that was operated in normal (i.e., not "unsafe" or critical) conditions to ensure the safety of the pilot and the UAV. The Tobii Pro Glasses 3 were used for raw data collection and the Tobii Pro Lab software for data analysis. Figure 1 shows an example of a gaze plot, examining if the pilot focused on the critical information on the screen while flying beyond the visual line of sight (BVLOS); the analysis focused on pilots with various levels of experience and flights switching from flying in the visual line of sight (VLOS) to BVLOS.

Figure 1. Gaze plot from a UAV flight

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