Conference Paper

Improved Pilot Training using Head and Eye Tracking System

Author(s):
Ferrari, Flavio; Spillmann, Kevin P. C.; Knecht, Chiara P.; Bektas, Kenan; Muehlethaler, Celine M.

Publication Date:
2018-01-14

Permanent Link:
https://doi.org/10.3929/ethz-b-000222482

Rights / License:
Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International
Improved Pilot Training using Head and Eye Tracking System

Flavio Ferrari (ferf@zhaw.ch), Kevin P. C. Spillmann (spik@zhaw.ch), Chiara P. Knecht (kneh@zhaw.ch), Kenan Bektas (kenan.bektas@zhaw.ch), & Celine M. Muehlethaler (muhe@zhaw.ch)

Centre for Aviation, School of Engineering, Zurich University of Applied Sciences, Switzerland

Abstract. As there is no common and standardized training content on the assessment of (instrument) scanning performance and situation awareness for pilots, an effective training concept is necessary to support pilots in achieving and maintaining appropriate scanning skills and to develop personal mechanisms in handling situation awareness. The present paper introduces a head and eye tracking system for pilot trainings in a flight simulator. This system is able to collect eye tracking data and merges it with either a simple 2D screen or a more advanced 3D model of the flight simulator. Thus, this procedure allows an automatic evaluation which provides data of the complete flight training, e.g. fixations in predefined areas of interests, scanning paths or heat maps. The system is used in the research flight simulator of the Centre for Aviation. Upgrading the system will bring also advantages to various research fields.

Keywords. Head and Eye Tracking, Pilot Training, Scanning Behaviour, Automatic Evaluation

1. Introduction

Situation awareness is one of the most critical and challenging aspects of a pilot’s job (e.g. for a review of military aviation mishaps see Hartel, Smith, & Prize, 1991; for accident analysis involving major airlines see Endsley, 1995). Although automation is common in today’s airline cockpits, pilots still have to monitor instruments and the autopilot. To keep situation awareness during the mission, a well-performed and standardized scanning procedure of the flight deck's instruments is essential. Especially in high workload situations, intuitive behaviour such as evolutionary-based human automatisms
(e.g. pushing the aircraft’s nose down when it is stalling) helps to remain in charge of the situation (Muehlethaler & Knecht, 2016).

Nowadays, flight instructors only have modest tools to observe the flight student’s point of gaze during the flight trainings. Sometimes flight instructors provide a solution by using small mirrors to have a better view of the student’s eyes. If the training occurs in a flight simulator, there is also the possibility to sit behind the flight student. However, these methods do not allow to follow the student’s scanning technique in detail. Hence, an incorrect scanning procedure of an aircraft’s instrument panel is only apparent when flight parameters like airspeed, altitude or heading deviate out of tolerance. Moreover, the mistake’s origin remains hidden in many cases since they are difficult to detect. The flight instructor’s task does not only include the observation of the flight student’s view, i.e. his scanning path, but also to pay attention to other activities for instance the manipulation of instruments or flight simulator settings. Certainly, there is the option to hire an extra person to solely check the scanning skills. However, this would require additional resources. Furthermore, the available space in a simulator cockpit is limited in most cases. The obvious solution to enhance training outcomes by training scanning behaviour during flights seems to be eye tracking (e.g. for a successful implementation of eye tracking in a flight simulator environment see Wetzel, Anderson & Barelka, 1998).

Eye tracking research so far reveals that the evaluation of video material is time consuming (see Ali-Hasan, Harrington & Richman, 2008). Therefore, efforts to reduce the data processing time when using eye tracking systems are necessary and leads to the idea of an automatized data processing, i.e. the complete data analysis is computerized and programmable. If eye tracking is used for training purposes, this problem becomes more evident, as the transfer effect of learned knowledge is higher after an immediate feedback, meaning that the debriefing should be held immediately after the flight training (Dufrene & Young, 2013). An automatized analysis approach of the pilots’ scanning behavior would reduce the time cost of currently available methods. Referring to De Smet et al. (2012), different forms of automatized eye tracking processing are available. However, various requirements – e.g. the head must stay in a fixed position – make these setups impractical to use in a flight simulator or other similar dynamic locations, e.g. automobile industry. It becomes more complicated when several areas of interest are not in the same layer but in various angles to each other, e.g. a complex or multi instrument dashboard. Weibel and colleagues (2012) combined eye tracking with additional head tracking data in order to elude this problem. Whereas their approach was either by using IR tracking points distributed on the instrument panel or by computer vision techniques (OpenCV), the system presented by the authors implements the tracking information directly on the eye tracking glasses, which allows a higher spatial resolution of the pilot’s head position.
Yet another solution is provided by SmartEye (2016), which works with a standard camera combined with IR flashes mounted on a dashboard for analysing a person’s head position and point of gaze. However, neither Weibel et al. nor SmartEye account for an automatized eye tracking data processing for a dynamic environment as it is described by the authors’ system.

To summarize, for an effective flight training evaluation, there is a strong need for an eye tracking enabled flight simulator that can collect 3D head and eye tracking data. Additionally, automatized data processing allows an immediate feedback during and/or after the pilot training.

2. System Capabilities

For an automatized processing of eye tracking data, there exist two possibilities so far: a) by using digital image processing, i.e. each frame is analyzed by a computer algorithm, and b) by using glance vectors, i.e. the path along the line from a human’s eye to a focused object (point of gaze) depicted as a (mathematical) vector. Each option has its advantages and disadvantages. Digital image processing requires high implementation effort and demand of computational power as well as good and stable light conditions. Hence, it is unsuitable for a setup inside a flight simulator. This leads to the consequence of developing a system based on the glance vector solution.

The hardware consists of two main components: the eye tracking glasses from SensoMotoric Instruments (SMI), in particular the Eye Tracking Glasses® (ETG 2), and the motion tracking system from Advanced Realtime Tracking (ART), in particular the DTrack® software, for head tracking. A screen with the pilot’s view and point of gaze is available for an observer or instructor during the training session. To track head movement, four cameras were installed around the flight simulator cockpit, as illustrated in Figure 1. As a reference for the cameras, the eye tracking glasses were equipped with tracking points. While the glasses deliver the glance vector \( \hat{g} \) relative to the head, the head tracking system records the head position and orientation relative to the simulator cockpit, i.e. the base vector \( \hat{b} \). The absolute glance vector \( \hat{x} \), i.e. the vector relatively to the complete system, is then calculated as \( \hat{x} = \hat{b} + R_H \cdot \hat{g} \), where \( R_H \) is a rotation matrix containing the angles of the head orientation. The point of gaze is further calculated as the position where \( \hat{x} \) intersects with the surface of the 3D simulator model, i.e. mathematically a plane surface.

![Figure 1. IR tracking cameras on one side of the flight simulator.](image-url)
Concerning the automatized data processing, the Center for Aviation has developed a software code written in C++ and named it Sim-Qt. This in-house application merges both data from the eye and the head tracking system and applies them to a 3D CAD model from the simulator cockpit. This sequence is illustrated in Figure 2 and describes the complete data acquisition procedure.

The data can further be analyzed with the program MATLAB from MathWorks™ for which a script was written as well. Along with the previous calculated intersection points, a configuration file that includes the defined area of interests (AOI) is needed. At the end, various evaluations of eye tracking data, e.g. fixations, saccades, blinks etc., including statistical calculations and visualization methods, e.g. heat maps or scanning paths, can be performed automatically, as illustrated in Figure 3.

This method allows a debriefing immediately after a training session with actual information about the pilot's scanning behavior. Furthermore, this system does not only account for a 3D environment, but can also be implemented in a simpler 2D setup, e.g. for air traffic controllers or drone operators.

However, the system is limited by the detection capabilities of the eye tracking glasses, i.e. only eye information within the perception box can be evaluated. In addition, the first implementation of such a system might be time consuming. Nevertheless, as soon as the equipment is installed and configured, this issue is resolved.
3. Discussion

3.1. Chances and risks
The head and eye tracking system offers diverse application possibilities for research and practical training development such as for flight crews, UAV (unmanned air vehicle) operators, air traffic controllers or also in other sectors, e.g. the automotive industry or medical surgery. As customized results from data assessment are available right after a flight session, the information about eye movements and scanning behavior can be used in flight debriefings and thus permit an individual biofeedback-based debriefing for flight students. Consequently, this allows to understand and quantify human-based behavior in an objective way. Moreover, flight instructors have less workload during the test session as they can focus on other parts of the training and resort to unbiased recordings. Not only do student pilots benefit from the automated evaluation, also experienced pilots may improve their skills.

Furthermore, the system allows for a great amount of data sampling whereas the time of data analysis is reduced in contrast to common eye tracking systems. This enables eye tracking researchers to get new insights into flight behavior of pilots such as scanning behavior and situation awareness by analyzing a large amount of merged data.

Whereas many flight training sessions (or equivalent training situations) require similar analyses from the head and eye tracking system, other test environments may need some adaptions in the output data files. The conversion of raw data to diagrams is relatively straightforward. Therefore, a study design and the requirements for the measurements must be defined carefully. Nevertheless, this method allows a profound analysis and delivers additional value for flight students and flight instructors.

3.2. Outlook
So far, a usable version of Sim-Qt is already in service. Nevertheless, it is improved continuously and fitted with additional features. One next step might be to assess whether the head and eye tracking devices are causing any distraction for the flight students. Additionally, improved feedback and evaluation in upset prevention and recovering trainings (unusual flight positions like stalls or vrille) or similar fields can now be conducted. To expand research potential, external parameters, e.g. an EEG or pulsoximeter (measuring pulse and oxygen), might be considered to track a pilot’s physical state, especially his stress level. The data set might also be supplemented with a system status, e.g. the aircraft’s attitude or speed, or many other factors affecting human behavior, depending on the field of research, e.g. with hand
tracking data. Besides the various possibilities for such systems, the time saved due to automatized data processing allows to conduct studies with considerably more participants then nowadays. With minor modifications, our system can easily be adopted to these prospective ideas and opens the possibilities for further research.

References


