IMPLEMENTATION OF A SYSTEM FOR MONITORING BIO-PHYSIOLOGICAL DATA OF PILOTS VIA A FLIGHT SIMULATOR

Stefan Stavrev, Dimitar Ginchev

Abstract. *In recent years, there is tendency for information overload of private citizens, as well as various professionals – policeman, teachers, fire fighters, airplane pilots, and astronauts. The resulting stress can be extremely hazardous, especially for high-risk professions – people who are responsible lives of many others. That is why, one of the objectives of the current research paper is to create a monitoring system, capable of gathering, analyzing and storing bio-physiological data of high-risk professionals. For the implementation of that system, we use a commercial-grade VR flight simulator for training airplane pilots. In addition, we gather data via different sensors that measure the pilot's performance under stressful conditions. Finally, we analyze the data and draw conclusions.*

Key words: bio-data monitoring, simulators, sensors, serious games.

Introduction

Monitoring systems are developed in different contexts – to supervise automation processes in factories, for surveillance purposes, child care, as well as in high-risk professions. In this paper, we focus on the latter – to implement a system that monitors and later analyses a commercial pilot's performance under normal operating conditions, as well as under pressure. The choice to monitor, record and analyze pilots' performance is not arbitrary – the latest EASA [1] regulations changes, called "Knowledge, Skills & Attitudes", KSA100 [2] require commercial flight attendants and pilots undergo additional monitoring and more strict examinations. This requirement is part of the ATPL [1] Integrated pilot training.

Information overload in different professions can lead to several kinds of ineffective work. Overloading may be of mental nature, stress, physical labor, nausea, etc. This is the reason behind the creation of an aviation training simulator at the Faculty of Transport of the Technical University of Sofia. The basic simulator setup (which consists of a powerful computer, a LCD monitor and operational controls) is extended by adding a new module. The new add-on, presented in this paper consists of sensors and VR devices capable of detecting various kinds of information overloading. Using the presented add-on for such experiments is not only desirable, but also mandatory under the latest KSA100 requirement. The reason behind it is these kinds of measurements are risky to be carried out during actual flights [3]. In addition, using a simulator is the preferred cost-effective method of operation. The flight simulator add-on is thus capable of detection of any discrepancies or early signs of stress or fatigue to potential pilots. As we know, commercial vehicles, such as airplanes, get upgraded with ever-growing number of navigational and communicational panels [4]. Tracking and making sense of all that information while keeping an eye on the avionics and handling the airplane is quite challenging, especially for young pilots. Physical preparation is as important as mental one. Introducing a monitoring system early in pilot training can mitigate risks, related to dangerous scenarios, such as flying in cloudy weather, landing and taking off at night, breaks in communications with tower control, etc. [5].

System setup

The proposed monitoring system – an add-on to the existing flight simulator, includes the following components.

First, a powerful desktop computer with high-end CPU and GPU, able to handle the highly-demanding simulation virtual environment, process monitoring and visualization, as well as gathering and analysis of all data, related to the experiment. This component is shared with the existing flight simulator and serves as a base processing hardware unit. In addition, we needed an appropriate flight simulation software, where the instructor is able to change dynamically the weather conditions, flight paths, start and destination airports, generating different airplane failures at certain times. Last but not the least, the simulation software should be able to record individual performances in a meaningful and easily portable data format, so that several participants can be tested and their piloting results can be easily compared. Furthermore, the monitoring system should include sensors for measuring blood pressure, pulse, skin galvanic response, and breathing frequency. An addition requirement is the inclusion of a commercial-grade VR headset capable of tracking a pilot's eyes, gaze point and eye movements across the virtual cockpit, as suggested in similar studies [6, 7]. Finally, two monitors are needed: one for the instructor who will change the flight parameters and conditions during flight (already part of the flight simulator) and one for visualizing the pilot's field of view and focus point (part of the proposed monitoring add-on). The complete add-on monitoring system can be viewed in Fig. 1, together with the already existing flight simulator.

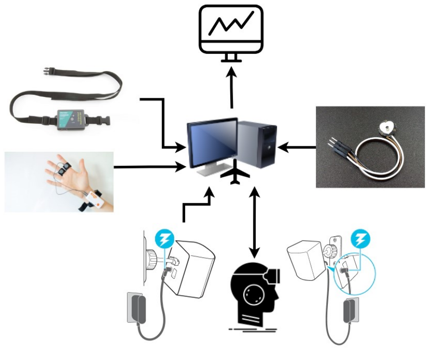

Figure 1. Monitoring system add-on for airplane pilot simulator

Before system completion there were several demonstrations and tests with potential users. The current version of the monitoring system includes the above-mentioned sensors because heart-rate, skin galvanic response and respiratory frequency measurements are of utmost importance. Analyzing similar monitoring systems [6, 7, 8, 9, 10, 11, 12, 13, 14] lead to the conclusion that gaze monitoring is unique and also quite important in aviation. There are good practices how to train a pilot's gaze to keep track of several gauges at once. The constant tracking of those gauges and avionics are more important in aviation than in regular car driving since a higher risk is involved. With the selected commercial-grade VR headset, eye tracking is available out-of-the box and can easily be integrated into the monitoring system add-on.

For the actual implementation of the monitoring system, we have selected the *X-plane simulation software* for several reasons. Firstly, it is available off-the-shelf and has integrated support with major VR manufacturers. Secondly, it supports common steering pedals and joystick controls that we use for manipulating the aircraft. As for the VR headset brand, we have chosen the Varjo VR-3. The technical specs of the VR headset are: uOLED integrated display, with resolution of 1920 x 1920 px. per eye, peripheral area at over 30 PPD LCD, 2880 x 2720 px. per eye, colors: 99% sRGB, 93% DCI-P3. This high resolution eye displays are able to render high quality images, increase the immersion factor and reduce VR motion sickness [10, 12]. Varjo VR-3 has a build-in tracking sensor that operates at 200 Hz. This means that it is able to take note and record a pilot's eye location, pupil diameter, gaze point estimation in the virtual environment, as well as head position and view direction. In addition, the Varjo VR-3 has built-in support for SteamVR 2.0 positional tracking sensors, which we also included as part of the monitoring system (Fig. 1). The positional tracking sensors, also known as base stations, operate at 100 Hz, have a 160° horizontal and 115° vertical tracking field of view and are able to track up to 7 m. The heart rate sensor is a common optical sensor. The respiratory sensor is a Go Direct Respiration Belt, with USB and Bluetooth connectivity support. Last but not the least, the galvanic-skin response device is the Grove – GSR_Sensor v1.2, which provides analog readings.

In this paper, we focus on experimenting with the eye positional tracking and measuring their focal point onto the airplane avionics and gauges. The built-in eye-racking allows to collect data (left eye position, right eye position, left eye focal point, right eye focal point, gaze estimation point, timestamp of the measurement) at 200 Hz. The collected data is available in CSV (comma separated value) file format. We store it on a file server for later analysis.

Experiments and results

The actual experiment begins after a test subject puts on the VR headset and starts the flight simulator program. The purpose of the experiment is to gather as much bio-psychological data as possible prom the pilot's performance. For this experiment, we have included 4 people doing several 20-minute control flights. We have fixed the pilots' field of view, so that we can record consistent eye-tracking data. The tasks that are given to the pilots are to keep track of several gauges and navigational controls, as well as to reach the final destination. The aircraft for the experiment is Cessna 172. The instructor monitors the reaction times of the pilot's eyes as he gives him flight directions. The flight task includes taking off and lending on Sofia international airport. The pilots have to almost simultaneously keep track of: airspeed, compass direction, engine stress levels, ground speed, air map, aircraft angle of attack, etc. The data the system gathers is the gaze point inside the virtual scene where the pilot is looking at a certain time. Overlaying that gaze point and constantly mapping it to the flight footage (by timestamp) we can determine whether each pilot is paying attention to the instruments, how much time he is spending looking at a certain instrument, on which instruments he is focusing more and on which – less. The raw output data of one pilot run is presented as a supplementary material.

After recording several participants in this experiments, we can summarize the following results. All participants flew the same course and used the same aircraft – the Cessna 172. The shown data is from a single experienced pilot (Fig. 2).

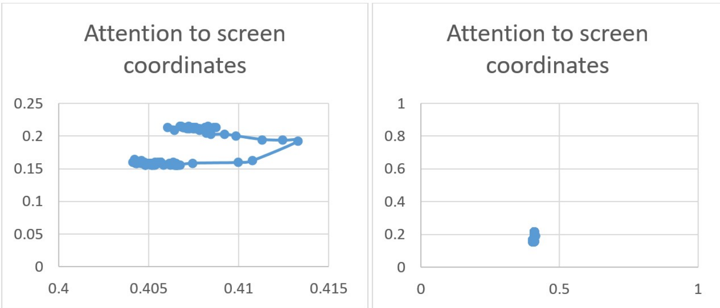

Figure 2. Zoomed-in view on pilot's attention gaze in screen coordinates (left) and normalized view (right)

As we see, the pilot's eyes move quite a lot (Fig. 2 left). On the vertical axis is the Y gaze coordinate, while on the horizontal axis is the X gaze coordinate. If we normalize and scale the plot to full screen coordinates (Fig. 2 right) we can determine the area at which the pilot is currently focused on. Mapping that gaze data to a video stream recording of the flight, we can draw a circle and visualizes on a more natural way the gaze point – the solid circle in Fig. 3. For comparison, we have overlaid the gaze data from an inexperienced pilot, as well (the hollow circle).

Figure 3. Experienced pilot gaze point (the solid circle) and a young pilot gaze point (the hollow circle) mapping from VR headset

In this particular instance, the experienced pilot was paying attention to all the gauges and avionics – his gaze point was over the artificial horizon, where it is supposed to be. This consistent and correct pilot behavior can be explained in several ways. First, that particular pilot has more than 10 years of experience in flying commercial airliners. The second reason for the correct and timely eyeing the instruments is the current evaluation scenario is run in mildly cloudy skies, during daytime, which is considered a medium intensity scenario. For comparison, even in these conditions, the inexperienced pilot has some difficulty to focus his gaze upon the correct instruments, during the same time of the flight (compared by timestamp). It seems the young pilot is hesitant and still has to learn to master his self-control. Fortunately, conducting these experiments and measurements is done in a safe simulation environment without actual hazard.

Conclusion

In this paper, we have presented a monitoring add-on system that can be integrated with existing flight simulators. The system can measure several bio-physiological metrics, although in this paper we have focused on measuring eye gaze. The eye gaze estimation can successfully predict, plot and compare the gaze points of several pilots, flying the same course and the same environmental conditions. It can be a powerful tool that can be used in latest KSA100 mandatory annual pilot evaluations.

Acknowledgments

The author would like to thank to the project MU21FMI007 for the financial support for the current research.

References

[1] EASA, `https://www.easa.europa.eu/en`, (accessed on 20.11.2022).

[2] KSA100, `https://www.path2pilot.com/news/ksa100-training--assessments222`, (accessed on 20.11.2022).

[3] Y. Kasuya, S. Moriwaki, C. Inano, T. Fukada, et al., Feasibility of the head-mounted display for ultrasound-guided nerve blocks: a pilot simulator study, *Journal of Anesthesia*, Vol. 31 (5), 2017, 782–784, ISSN: 1438-8359.

[4] M. Bosch Bruguera, J. Bermudez, et al., Development of a Virtual Reality space docking simulator for research and training – A case ap-

plication in the space analogue SIRIUS-21, Proc. of *73rd International Astronautical Congress (IAC)*, Paris, France, 2022.

[5] A. Perez, H. Moncayo, A. Togayev et al., Pilot-in-the-Loop Evaluation of a Bio-Inspired Adaptive Fault Tolerant Control System in a Motion Based Flight Simulator, AIAA 2015–1313, Proc. of *AIAA Guidance, Navigation, and Control Conference*, January 2015.

[6] J. Bürki-Cohen, A. Kendra, Air Traffic Control in Airline Pilot Simulator Training and Evaluation, *Air Traffic Control Quarterly*, 2001, Vol. 9 (3), 229–253.

[7] M. Wei, S. Fang, J. Liu, Design and Implementation of a New Training Flight Simulator System, *Sensors*, Vol. 22 (20), 2022, 7933, ISSN: 1424-8220.

[8] A. Adami, D. Tonon, A. Corica, D. Trevisan, et al., Poor performance of screening questionnaires for obstructive sleep apnea in male commercial drivers, *Sleep and Breathing*, Springer, Vol. 26 (6), 2022, 541–547, ISSN: 1520-9512.

[9] I. Tarba, M. Gaianu, S. Stefaniga, The Driver's Attention Level, Proc. of *22nd International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC)*, 2020, 251–258.

[10] E. Abbasi, Y. Li, A Comprehensive Review of Driver's Attention and the Evaluation Methods, *CRPASE: Transactions of Industrial Engineering*, Vol. 7 (3), 2021, ISSN: 2423-4591.

[11] I. Velcheva, D. Peykova, Real world problem-solving through engineering, *Education and Technologies Journal*, Vol. 12 (2), 2021, 482–487, ISSN: 1314-1791.

[12] Q. Bi, X. Ji, Y. Sun, Research on Driver's Gaze Zone Estimation Based on Transfer Learning, *2020 IEEE International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA)*, 2020, 1261–1264.

[13] S. Yang, K. Yu, T. Lammers, F. Chen, Artificial Intelligence in Pilot Training and Education – Towards a Machine Learning Aided Instructor Assistant for Flight Simulators, *Communications in Computer and Information Science*, Springer, Cham, 2021, Vol. 1420, 581–587, ISSN: 1865-0929.

[14] Q. Li, et al., Human-Machine Interaction Efficiency Factors in Flight Simulator Training Towards Chinese Pilots, *Advances in Intelligent Systems and Computing*, Springer, Cham, 2021, Vol. 1206, 26–32,

ISSN: 2194-5357.

Stefan Stavrev[1,*], Dimitar Ginchev[2]
[1] "Paisii Hilendarski" University of Plovdiv,
Faculty of Mathematics and Informatics,
236 Bulgaria Blvd., 4003 Plovdiv, Bulgaria
[2] Technical University of Sofia, Faculty of Transport,
8 Kliment Ohridski Blvd, 1756 Sofia, Bulgaria
Corresponding author: stavrev@uni-plovdiv.bg