Review of possibilities in the EYE-TRACKING LAB for the safety of process control operators

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ABSTRACT

To enhance the level and quality of safety in industrial automated systems, there exists a wide array of technological solutions and methods. One such promising technology in this field is EYE-Tracking LAB. It allows for the analysis of various risks, thereby contributing to their prevention. In this scientific article, new and potentially in-demand directions are discussed and an overview of existing solutions using EYE-Tracking. The main statement for EYE Tracking Lab is to use a comprehensive system to track EYE movement and perform automated analysis of cognitive states, thereby enhancing safety and efficiency for operators using industrial automated systems. The method for diagnosing the operator's attention and fatigue in working with large and complex automated control systems in various industrial sectors, such as petrochemicals and energy, is described. As of today, the EYE-Tracking LAB technology is actively employed in various fields. Additionally, it proves to be cost-effective and efficient in its application.

1 INTRODUCTION

The human factor is an integral part of managing various technological processes. In conjunction with both full and partial automation of the process, people always tackle complex tasks by creating and implementing reliable criteria for the safety of managing technological processes. The main observation of the correct and safe operation of the technological process is carried out and implemented by operators of technological processes. Performing high-tech work, they ensure uninterrupted and continuous production. While monitoring complex production, the operator utilizes everything necessary for it. For example, means of control, additional settings, remote control methods, as well as the disconnection and switching of various devices in the important chain of devices and equipment of the technological process.

2 BACKGROUND

The human factor is an integral part of managing various technological processes. In conjunction with both full Due to the high workload, operators are susceptible to fatigue, exhaustion, and saturation at their workplace. This often leads to erroneous actions and inactions in solving complex and urgent tasks in managing the technological process. As a result, there is a risk that sudden incidents occur due to the human factor, leading to incorrect operation of the technological equipment, thus potentially causing damage, breakdowns, and even more serious consequences, including injuries and fatalities.

The petrochemical industry experiences losses of up to $10 billion dollars annually due to preventable workplace accidents. If not controlled and regulated properly, petrochemical processing can be volatile and may lead to catastrophic incidents, which is why safety is such a high priority [1].

For these reasons, the demands for proper and flawless work from people in production, including operators, are increasing. Even with the provision of all necessary facilities at the workplace, including the use of comfortable workstations with high-tech equipment, there remains a high probability of human error. One of the many solutions that allows for the diagnosis of operators' conditions is EYE Tracking Lab.

Eye-tracking has been used to observe expert strategies as an alternative to the think-aloud technique (users vocalize what they are looking at, thinking about, and doing). Eye-tracking allows researchers insight into behaviour with minimal interruption and into periods when the users are not aware of their own behaviour.[1]

Currently, there are numerous devices available for using EYE Tracking Lab, with brands from various manufacturers. Every year, these devices are evolving. Enhanced versions of these devices can be found on the market, thereby improving the analysis quality of assigned tasks. The sensors of these devices are becoming more sensitive. The reliability of the entire device is increasing, allowing it to be used not only in laboratory environments but also in production settings. For instance, in places with poor or unstable lighting conditions. Different device sizes enable users to choose the appropriate size, leading to comfortable usage due to good fixation. Built-in batteries increase the tool's operational time, making it highly stable for prolonged use. The latest enhanced versions of these tools may also incorporate Artificial Intelligence (AI). An example of AI's capability is to compare received online data with existing templates and then provide feedback for analysis. With AI, it's also possible to obtain information from the eye instrument through sensors and to filter faults and deviations by scanning.

Below, using the example of the "EYE-ETV EYE TRACKING GLASSES SYSTEM,"[2] let's consider the main technical specifications of the tool, which are as follows: scene camera, gaze tracking range, sampling rate, eyewear compatibility, parallax compensation, glasses weight, calibration, human interface design, wireless control, validation, gaze tracking accuracy, scene camera field of view, audio, scene camera interfacing.

Head-mounted SMI ETG, Senso Motoric Instruments Eye-tracking Glasses, (SensoMotoric Instruments, Inc., Boston, MA) recorded and analysed eye-movement (Figure 1). SMI ETG are portable and allow the head and neck to move freely. SMI ETG are binocular tracking devices that have two small cameras on the rim of the glasses (one camera recording the left eye and one camera recording the right eye) and an HD scene camera on the front of the glasses. The two small cameras capture eye movements and map the point-of-regard (where the eye is focused) into the scene video (SensoMotoric Instruments, 2011b). The SMI ETG system uses iView (SensoMotoric Instruments, Inc., Boston, MA) to record eye-tracking data. SMI’s BeGaze software was used for analysis [1].

Figure 1 - SMI eye-tracking glasses used during the experiment [3]

Tobii Pro Glasses2, which is from Tobii (Sweden). The device is divided into a data acquisition unit and a data recording unit, as shown in Figure 2. The acquisition unit is shaped like a pair of glasses and collects the spatial 3D coordinates of the eye through six infrared cameras around the frame; the recording unit uses a built-in software algorithm to construct a 3D model based on the eye coordinates to calculate the location of the gaze point and obtain a video of the scene from the human eye perspective with a gaze sampling rate of 50 Hz. With software Tobii Pro Lab [4]

Figure 2. Eye-tracking experimental setup consisting of (a) a data acquisition unit and (b) a data recording unit [5]

The gathering of information occurs with the help of sensors, which are positioned both inside and outside the tool. The internal sensors of the tool analyse the pupils and corneas of the eyes.

Below are the methods of EYE Tracking Lab. Gaze fixation, this method is used to track the exact moment when the eyes focus on a specific object or point of interest; Eye movement measurement, this method analyses the trajectory of eye movement when viewing specific content or performing a particular task; heatmap analysis, this method creates a heatmap showing the areas on which the subject's eyes are focused during a certain period of time. Fixation time study, this method measures the duration of time during which the eyes remain fixated on a specific object or area.

The principles of operation of EYE Tracking Lab. From the perspective of eye tracking data, the process starts from the first eye tracking point to the last eye tracking point. Therefore, the sign perception time is the time span between these two points. Based on the relative position between evacuees and evacuation signs at the time the last eye tracking point was obtained, we can calculate the perception distance and perception angle range. Assuming uniform linear motion between two timestamps of the trajectory data, we use linear interpolation on the trajectory data to align the eye tracking data [6].

Frequent errors or malfunctions that must be addressed include failures in reading the position of the retinal network and the eyes; please see Figure 4. However, modern, and even more technological instruments, which contain even more improved and sensitive sensors, mitigate this failure, thereby enhancing the quality of data collection.

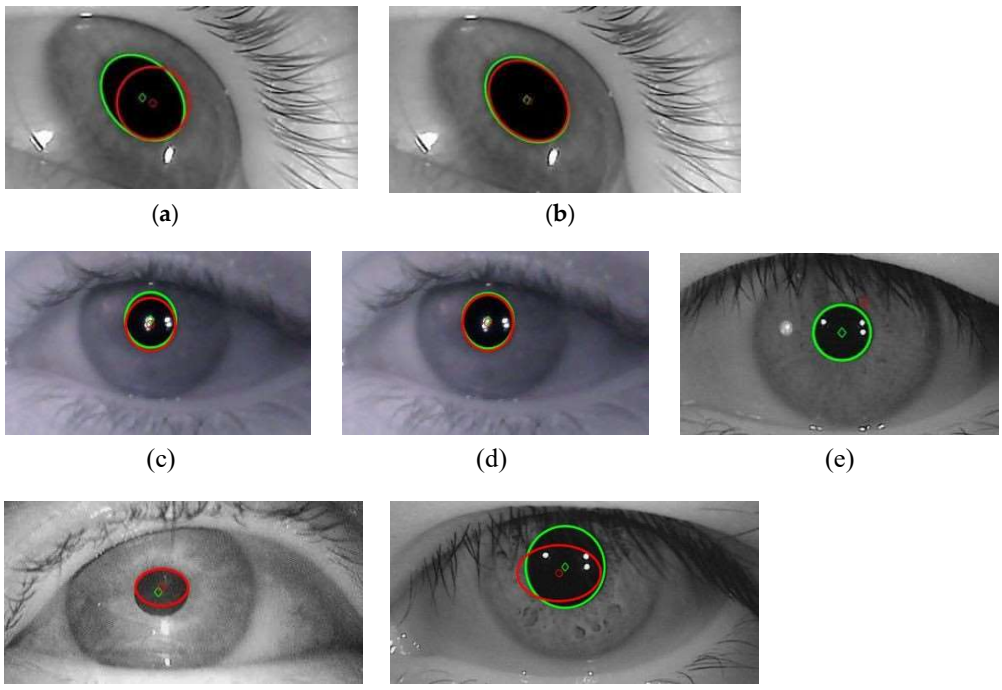

Figure 4. Typical detection errors of analyzed PDAs [7]

Typical detection errors of analysed PDAs: (a) CHT, detection error due to elliptical shape of the pupil; (b) EHT, cancelling the error introduce by CHT algorithm; (c,d) RANSAC, two different runnings on the same eye image with corneal reflection; (e) ExCuSe, loss of detection in an image affected by corneal reflection and occluded by eyelashes; and (f) PROJ and (g) LSFE, images sensitive to binarization stage (noisy eye image or pupil with occlusions). Legend: Green line—ideal pupil contour and center; red line—detected pupil contour and center [8].

One of the many functions that needs to be performed before using EYE Tracking Lab is automatic calibration. It automatically adjusts the subject and takes measurements of their eyes relative to the specified data collection settings via sensors. Figure 2.

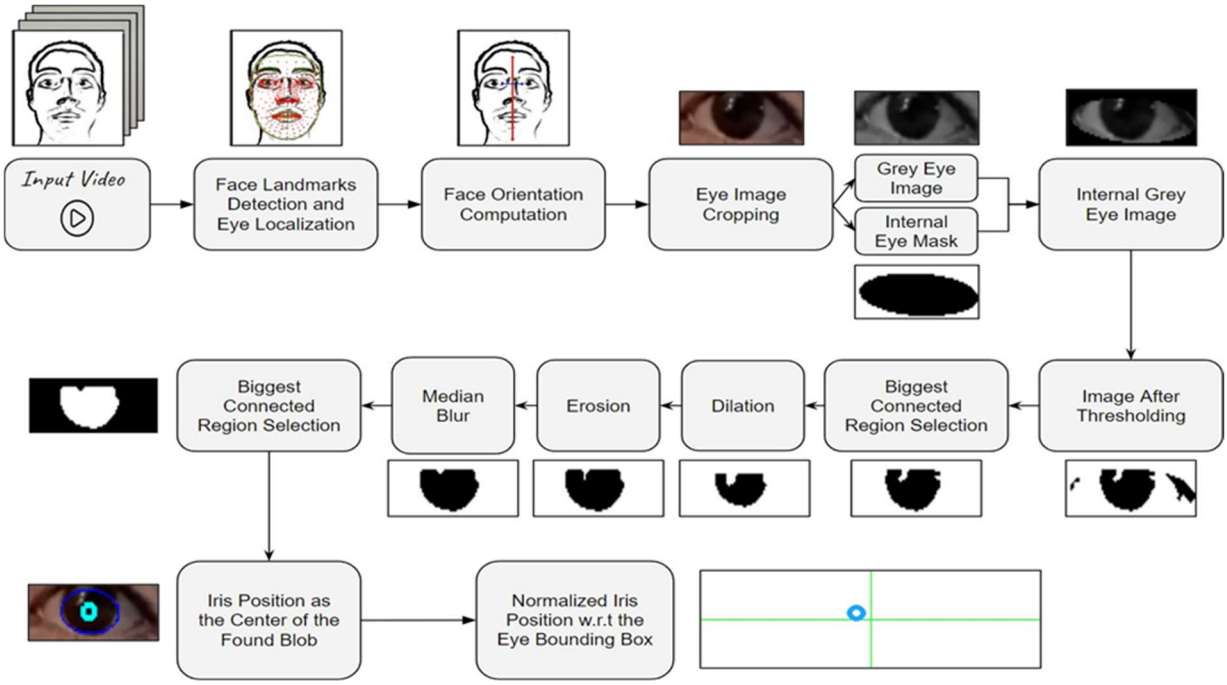

Figure 5. The Iris Detection Algorithm pipeline begins by detecting facial landmarks using the Face Mesh function on an image captured by the webcam [9].

The interfaces that display the analysis of data about the subject are connected to the EYE Tracking Lab instrument via Wi-Fi and Bluetooth. These interfaces serve for viewing and analysing data. The data is stored on memory cards with the capability of storing and processing large volumes of information.

The information is collected using sensors located both inside and outside the instrument. The main principle of analysis and information gathering occurs through Automated Optical Inspection (AOI).

Currently, there is a large number of applications utilizing EYE Tracking Lab and applied in various fields.
For example: psychology and neuroscience; marketing research; user experience design; education; human-computer interaction; sports science; analysing visual search strategies and decision-making in athletes during competition; driving research; virtual reality and augmented reality; market research.

Can Eye Tracking Lab can be used to monitor operators' visual attention and fatigue levels during complex tasks in industrial settings. By analysing gaze patterns and eye movements, supervisors can identify periods of decreased alertness or distraction, allowing for interventions to maintain safety and efficiency. Enables researchers to analyse how operators interact with control systems and interfaces in real-time. By studying visual attention and interaction patterns, improvements can be made to interface design and layout, reducing errors and increasing productivity. Or can be utilized in training programs for operators to enhance their skills and decision-making abilities. By providing real-time feedback on gaze behaviour during simulated tasks, trainees can learn to prioritize information effectively and improve situational awareness in high-pressure environments.

Using EYE Tracking Lab, it is possible to identify various other harmful external factors that adversely affect human work in large and hazardous productions. For example, the influence of lighting in workshops and production areas, optimization, and urgent evacuation in connection with emergency situations; optimization of visualization of technological processes on displays for operators, the impact of the time of day on the performance

of people working in productions; the influence of the external environment, such as dustiness, lack of oxygen, increased or decreased working temperature.

3 CONCLUSIONS

Please compare all this part by one text: Since our goal is to apply EYE Tracking Lab for operators of technological processes, based on the above, we can not only assume but also assert that using EYE Tracking Lab is highly effective for analysing the attention, fatigue, and drowsiness of technological process operators. Compared to other devices for testing or diagnosing human attention, drowsiness, and fatigue, EYE Tracking Lab has been proven to be easy to use. It can be used alongside current work tasks without interfering with or distracting from their execution. The low cost of the tool and its software does not entail significant financial expenses. Moreover, the significance of its usage always remains at a high level. One potential direction for future research for the EYE Tracking Lab could be the development of advanced algorithms or machine learning models to expand its capabilities in analyzing subtle changes in attention, fatigue, and drowsiness. With the ability to establish feedback for instant transmission of information to the operator, as a warning of potential risks associated with managing the production process in the workplace. The name "EYE Tracking Lab" refers to a comprehensive system developed for tracking eye movements. This system is designed to provide detailed data on the cognitive state of individuals, helping to minimize disruptions in the work process and providing valuable data for analysis. The methodology in the EYE Tracking Lab includes several key stages, such as attention, fatigue, and drowsiness among operators of technological processes. The system initially employs specialized hardware and software for eye tracking to precisely capture and record eye movements in real-time. Then advanced algorithms and machine learning models are used to process the collected eye tracking data. After data processing, the level of operator attention, degree of fatigue, and likelihood of drowsiness during task performance are evaluated. The core concept of EYE Tracking Lab involves equipment with specialized hardware and software. The equipment itself includes glasses equipped with sensors and cameras that contribute to the precise capture and recording of eye movements.

6 REFERENCES

1. Christina Marie Koffskey., *Using Eye-Tracking to investigate strategy and performance of expert and novice control room operators.* Louisiana State University, 2014.
2. Web page. https://www.biopac.com/product/eye-tracking-etv/
3. Figure 1. SMI eye-tracking glasses used during the experiment. http://eyetracking.tistory.com/14
4. Xiazhong Zheng, YuWang, Yun Chen, Qin Zeng and Lianghai Jin., *Influence of Safety Experience and Environmental Conditions on Site Hazard Identification Performance.* China, 2023.
5. Figure 2. Eye-tracking experimental setup consisting of (a) a data acquisition unit and (b) a data recording unit. https://doi.org/10.3390/buildings13010251
6. Lin Huang, Jianhua Gong and Wenhang Li., *A Perception Model for Optimizing and Evaluating Evacuation Guidance Systems.* China, 2021.
7. Figure 4. Radu Gabriel Bozomitu, Alexandru Pasarica, Daniela Tarniceriu and Cristian Rotariu., *Development of an Eye Tracking-Based Human-Computer Interface for Real-Time Applications.* Romania, 2019. DOI:10.3390/s19163630.
8. Radu Gabriel Bozomitu, Alexandru Pasarica, Daniela Tarniceriu and Cristian Rotariu., *Development of an Eye Tracking-Based Human-Computer Interface for Real-Time Applications.* Romania, 2019.
9. Figure 5. Emanuele Iacobelli, Valerio Ponzi, Samuele Russo and Christian Napoli., *Eye-Tracking System with Low-End Hardware: Development and Evaluation.* Italy, Poland, 2023.