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# THE WORKERS PERSPECTIVE - EYE TRACKING IN PRODUCTION ENVIRONMENTS

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***Abstract:*** *Eye tracking is the process of recording a person's eye movement for the better understanding of his/her visual perception. Due to low costs and highly accurate systems the process of eye tracking is used in devices and applications to increase computer interaction and to study human behavior. Eye tracking is used in a wide range of applications but is almost absent in the engineering domain (e.g., production processes). The cause could be that engineering is an exact science and product design is based on a rigorous set of physical, functional and legal constraints. This study deals with the usage of the Eye tracking technique in the automotive environment. Particularly, it will be used to optimize the quality assurance of paint and the manufacturing of head-up displays in automotive manufacturing. The objective of the studies is to examine the quality assurance cycles regarding optimized working conditions and improved production quality.*

***Key words:*** *Eye tracking, quality assurance, automobile production, working environments*

## 1. INTRODUCTION

Digitalization has changed the way companies communicate, manufacture and organize themselves. In the first phase of digitalization, companies mainly focus on the increase of productivity, efficiency and profitability through the integration of new technology to connect devices and machines, digital tools such as platforms, digitalized distribution channels or even digital business models. Only in the second phase, they realize, that not only the machines and methods must adapt to the changes resulting from digitalization, but it has also a great potential to improve labor conditions and working procedures on the shop floor. This means that the communication, orchestration and working methods change too and new ways and standards must be set [1; 2].

Eye tracking is the process of recording a person's eye movement for the better understanding of a person's visual perception. Due to low costs and highly accurate systems, the process of eye tracking is used in many devices and applications to increase computer interaction and to study human behavior.

The device used to record the movement of the eye is called eye tracker. It uses projection patterns and optical sensors to determine the eye's position, viewing di-rection and eye movements with very high accuracy. There are two possible eye tracking systems. One system is directly linked to a screen, whereas the eye tracking glasses are a mobile system, which does work with a battery and therefore can be used in different environments [3].

A great majority of eye trackers are based on the principle of corneal reflection tracking. The following measures can be tracked:

- Gaze direction and gaze points, used for the interaction with user interfaces and in behavioral research to determine what attracts a person's attention and for how long. Gaze direction, which last between 200-300 ms are cold fixations whereas saccades describe gaze movements until 30-80 ms [4];
- Eye presence detection, in this case the eye tracker must find the presence of eyes vital to the tracking operation and it can also be used to trigger devices;
- Eye position is the ability to calculate the position of the eyes in real time, such

features improve the performance of the eye tracker and are also used in gaming and auto stereoscopic 3D display systems;

- User identification, in this case the eye tracker is used as a biometric sensor for PC logging or door operations;
- Eyelid closure is used for monitoring a person's attention span and can be applied for driver assistance or user safety solutions;
- Eye movement and patterns are used to understand human behavior and diagnose diseases. It is possible to run a hearing test on infants. The study of micro saccades is also central in neurological research;
- Pupil size and pupil dilation is used to determine the user's excitement level or the influence of drugs and alcohol.

Eye tracking has become a powerful tool for understanding human behavior. The eye is directly connected to the information processed by the brain, which provides a simple method to study what a person is thinking [5].

## 2 AREAS OF APPLICATION

"Eye movement signals allow us to pinpoint what is attracting the user's attention and observe their subconscious behaviors. They can be important cues for context-aware environments, which contain complementary information for emotion recognition. The signals can provide some emotional-relevant features to determine the emotional states of a user. An investigator can estimate the emotion of the user based on the changes in their pupil size" [6].

An executed literature review shows that there are many areas, where eye tracking is currently used. Leading consumer goods companies use eye tracking to optimize product packaging and retail shelf design; market research companies and major advertisers use eye tracking to optimize print and TV ads; product companies use it to optimize interaction design; web companies use it to optimize online user experiences and the usability of their websites; universities use it for research in psychology, neurology and medicine. New types of medical diagnostics have also been made possible by eye tracking, as well as safety applications that monitor user attention in critical situations [7].

Studies using eye tracking can be categorized in four groups [8]:

1. Marketing and advertising – in this field eye tracking is used to observe the customer's perception of a product with the purpose of improving the products design so it will be more appealing to the targeted customer group or to verify if a product's label information is noticed correctly;
2. In neuroscience and psychology fields - eye tracking is used to study the effects of various diseases and the behavior and decision-making process of individuals in various health related cases;
3. Computer science and usability – in this case eye tracking is used as an input method for various devices and software;
4. In industrial engineering - present and future work environments and processes are analyzed using the eye tracking technology (singular experiences and not generalized practices).

As shown in the examples above, eye tracking is used in a wide range of applications but is almost absent in the engineering environment. One reason could be that engineering is an exact science and product development and design is based on a rigorous set of physical, functional and legal constraints and only after these requirements are met, the visual aspect is taken into consideration [1; 2].

Other examples of using eye tracking can be in the software environment as demonstrated in "Evaluating an eye tracking interface for a two-dimensional sketch editor" where it is used as another input method for a CAD software to improve the usability [9].

Another possible use is to record the customer's visual analysis of a prototype and see where the points of interest are. This is useful because it can lead to improvements in the product design beyond the requirements and needs expressed verbally. It can also be used to analyze how an assembly line worker perceives the working station and if there are any difficulties in locating the tools or mating points of the parts. It also can give a non-conscious feedback regarding the work activity.

Another application for eye tracking is in the quality control faze of a product. If a more complex product is made and the control needs to be done by an employee, his gaze can be recorded and then checked by a computer to see if all key zones of the product were analyzed [10].

## 3 A STUDY OF USING EYE TRACKING IN QUALITY CONTROL OPERATIONS

### 3.1 Set up

In this study the final quality control of a paint shop of a major European producer of transporters has been analyzed regarding the following aspects:

1. Order/sequence of how the employees of the quality control inspect the transporters in comparison to a given sequence;
2. How long are very sensitive parts/areas of the transporter, which are very vulnerable for damages, inspected?
3. How can the working environment and the work process of the quality control be optimized to improve the working conditions for the employees?

There are three different shifts working on the quality control of the paint shop five days a week 24 hours, including breaks. Taking part in this test was voluntarily for the employees. Because not all people are able to wear eye tracking glasses and generate useful data, the number of participants was limited. In total, six employees each from the early, late and night shift did participate in the study. Two different kinds of transporters with each two variants in lengths and choice of doors) are manufactured there. The transporter can be produced in 300 different colors, however 90% of them are white. For this study Tobii eye tracking glasses I (60hz, MJPG200 640 x 480) as well as questionnaires and observations sheets have been used. To prepare and evaluate the data, Excel from Microsoft Offices 2013 and the analysis software Tobii Professional have been selected.

The eye tracking glasses have been used to monitor the employee's eye movement as he/she checked the transporter for damages to the paintwork. Each tested employee did control three transports in a row, wearing the eye tracking glasses (Figure 1).

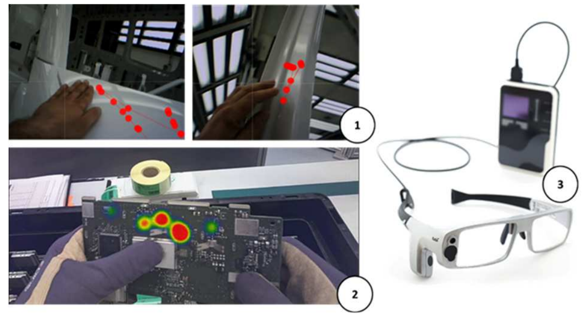



**Fig. 1.** Study objects paint control (1) and circuit breaker (2) and the eye tracking equipment (3)

While the employee was checking the transporter, he/she was observed at the same time regarding the following aspects: transporter (version/color), kind of control (visual/haptic) and itinerary. Afterwards the tested employee was asked the following questions [11]:

- Experience (years) in working at this part of the manufacturing process;
- Rotation within the work process of controlling;
- Physical fatigue;
- Difficult parts of the transporter to control;
- Parts of the transporter with most damages;
- Improvements to the working environment.

### 3.2 Procedure

The study took place at the final quality control at the paint shop within the car manufacturing process of the transporters. There is no given order, in which the different variations of transporters in length and color occur. This means that the production line is flexible enough to produce the transporters on demand. This leads to the fact that the employees working at the quality control of the paint shop must deal with different variations of transporters all the time. Furthermore, there is no specified changing modus/rotation modus when the employees change their position within the controlling process. In total 3-4 people are working each at three different control lines, to control the coated transporters; two employees are checking the transporter for damages to the paint.

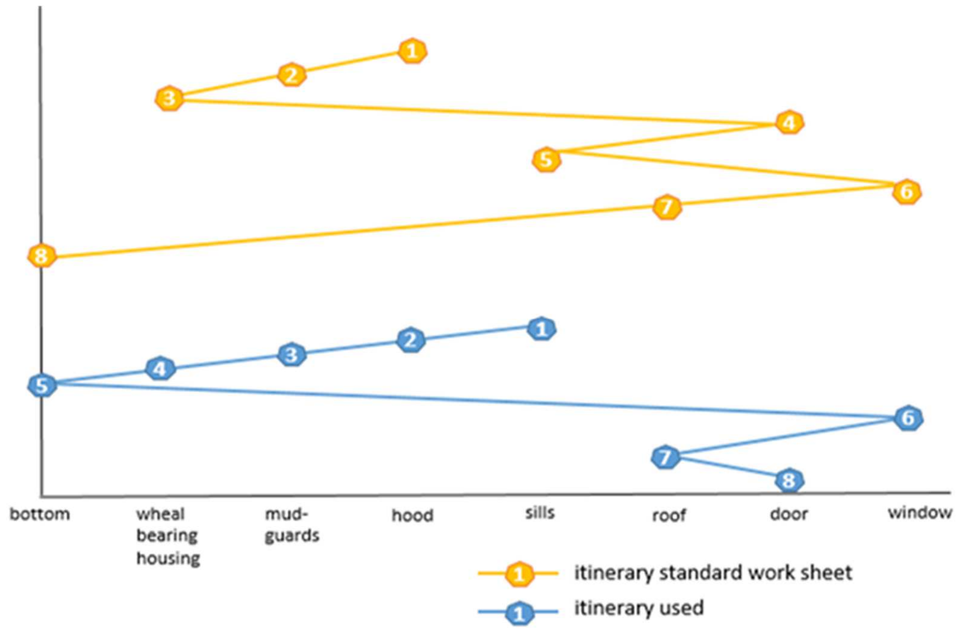



**Fig. 2.** Control sequence

According to the work instruction for the quality control, which is put on a notice board close to the production line, each employee is responsible for one site of the transporter. Parts of the internal areas of the transporter, which need to be checked as well, are equally divided between the two employees. The other employees are responsible for checking and repairing the damages to the paint.

The collected data will be analyzed with the software Tobii Professional using the following visualization tools [12]:

- Gaze Plot displays gaze data from one or several recordings as single gaze points, fixations, and scan paths. The order and length of fixations can also be visualized;
- Heat Map displays gaze data from one or several recordings as a heat map or gaze opacity map. A heat map gives an aggregated view of the results and can be based on fixation counts or gaze time;
- Cluster displays the areas with the highest concentration of gaze points as polygons.

### 3.3 Data Analysis

To receive a statistic of how and in which sequence the transporters are controlled the observation sheets as well as the filmed information from the eye tracking glasses have been analyzed and compared to the given work instruction. An analysis of the eye movement leads to a visualization of their scan paths and allows to display the employee's visual search strategy [13]. Figure 2 shows the given control sequence in comparison to the control sequence performed by the tested employees.

After analyzing the sequences taking by the 18 tested employees, one main itinerary was discovered. The blue line is the sequence which has been used most of the times. It differs from the given control sequence. As a result, the work instruction regarding the quality control needs be revised. The most used itinerary will serve as a base for an improved standard work sheet for controlling the coated transporter.

Statistics naming parts of the transporter, where damages to the paint have often not been found in the quality control of the paint shop are the area around the base of the front passenger seat and parts of the trunk of the transporter. Those damages are often recognized at different quality controls of the transporter later. Finding those damages at a later point of time in the manufacturing process means that there is a delay in time, because the damages need to be repaired, leading to higher production costs.

With the help of the eye tracking glasses and the included camera the accuracy of how those parts of the transporter are inspected in general shall be analyzed. To measure the accuracy of how those so-called sensitive parts of the transporter are controlled, the time used for checking those parts are compared to the total time used to check the transporter. For this special matter, the area around the base of the front passenger seat has been analyzed regarding the above-mentioned aspects. The Figure 3, filled with the information received from evaluating the films from the eye tracking glasses, shows that all employees tested spent too less time controlling the area around the base of the front passenger seat.

An average of 5 out of 116 seconds were used to check this area. Moreover, the evaluation using the Gaze Plot, Cluster and Heat Map analysis, as seen in Figure 4, shows that the employees did not focus and fixate the area long enough and that not all parts, belonging to this area, were looked at. The results of all 16 tested employees revealed that only 26% of the gazes in this area have been fixations.

In the meantime, only saccades were recorded. Only when parts are fixated, optical information can be perceived consciously [13]. Consequently, the employees should spend more time controlling critical parts, to avoid unseen damages to the paint. Possible solutions to approach the above-mentioned findings are to train the employees better and to name further control points at the area around the base of the front passenger seat, which need to be checked off.

One important aspect which has been analyzed as well is that how the working environment and the work process itself can be optimized in order to facilitate the work for the employees leading to a lower failure rate in finding damages to the paint of the transporter. The information needed for that was taken from the questionnaires and from the observation sheets. According to the answers of the questioned employees and their given priorities the following two points have been focused on: physical fatigue and ideas for improvement of the work environment.

Important findings of the questionnaire regarding the physical fatigue were that 60% of the questioned employees said that their eyes were tired after half of their working hours.

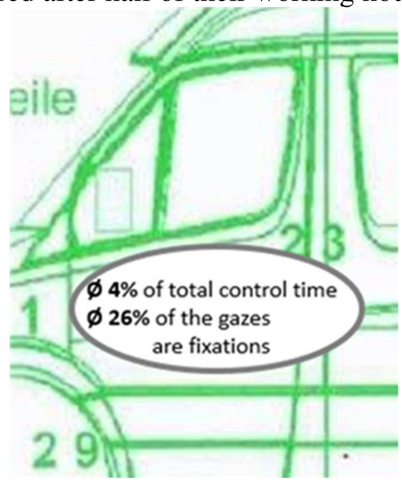


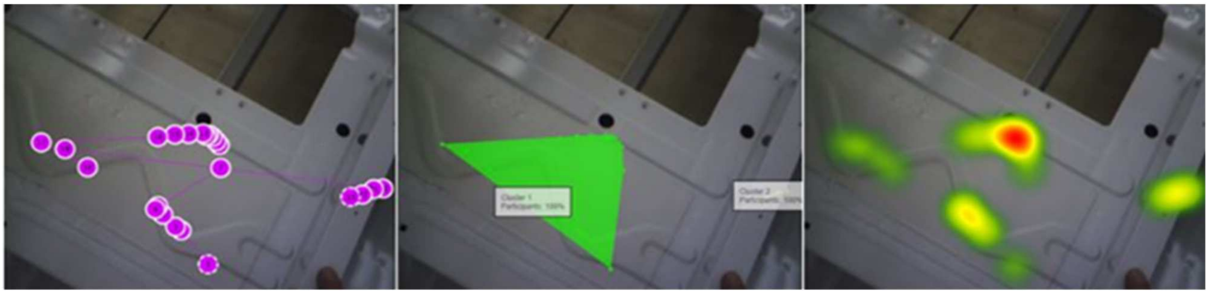

**Fig. 3.** Results evaluation critical area

After mentioning tired eyes, a lack of concentration was named to be a problem after 5 hours of working for 40% of the employees. The quality control is performed equally with the eyes and the hands, no matter how experienced the employees are.

The results from the observation sheet show that 85% of the mistakes are found with the eyes. Giving the employees the possibility to name any improvement, four out of nine mentioned ideas considered changes of the light conditions of the work environment.

Taking all the findings into consideration, improvements of the light conditions may lead to a better working environment in the way that the eyes will be less tired leading to a higher ability to concentrate and most probably to better results of the employees in general. Furthermore, exercises to relax the eyes shall be included regularly to the quality control and can easily be integrated when the employees are waiting for the new transporters to arrive [13].

Further on the analyses of the painting process as well as the assembly of the head-up displayed showed that the tools used to execute the work in several times do not comply with the specifications. It was observed that non-conform or inappropriate tools have been used in the work processes (e.g. dirty gloves in the check of



electronic functions, wrong stamps for work validation and signatures etc.).

**Fig. 4.** Heat map analysis

## 4 CONCLUSIONS

The study shows that using the eye tracking technique as a possible application to optimize processes in the engineering environment is possible. Several useful solutions have been found to optimize the quality control of the paint shop, to improve the work environment for the employees and to minimize the failure rate.

Another outcome of the study is that using only the results of the eye tracking glasses is not enough to receive a sufficient answer to complex questions in a manufacturing process. It can only be used as a complement to other evaluation methods.

The following three improvements for suggestions have been concluded:

1. The standardized work sheet for the quality control at the paint shop needs to be adapted to the actual applied itinerary. The mainly applied itinerary shows a more efficient and more comfortable way for the employees.
2. The analysis further indicates that standardized work sheets need to be adopted and compared to the actual work process regularly.
3. Because the results of the quality control could be visualized, the produced pictures and films can be used for enclosed training methods. The collected data can be the basis for a common fault analysis with management and employees. This will eventually lead to a better understanding and adaption of changes of the employees.
4. The results of the questionnaire demonstrate that some major improvements of the workplace environment are necessary. Better health conditions and a further protection of employee’s eyes will improve the health conditions in general leading to more satisfied employees and a better work outcome.
5. Several “deviations” from given standard procedures have been found and are now subject for additional quality trainings of the employees. One deviation has led to a total review and renewal of an existing standard procedure because the identified “As-Is” work procedure (executed by the workers currently on the shop floor) has proven advantages in preventing workers´ fatigue and improving the working conditions.

Regarding the development of lighter and more precise eye tracking glasses further applications in the engineering environment are possible. It is somehow still a pioneer work, using the eye tracking technology in this area [14; 15; 16; 17].

Already reached results show that there is a great potential, which needs to be built on to set up further standards using this technique. The method of examination and the findings will become part of both companies’ regular review procedures and are subject of further research in a European research project [18].

Future research will be possible by having a human resource skills development programs by adequate trainings and practical exercises. In addition, research innovation needs integrated engineering collaboration skills and thus, international projects are facilitated [19; 20].

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**Perspective ale lucrătorilor în urmărirea traseului ochilor în realizarea sarcinilor de muncă**

**Rezumat:** Urmărirea traseului ochilor este procesul de înregistrare a mişcării globului ocular (în cazul unui lucrător) pentru o mai bună înțelegere a percepției sale vizuale n realizarea sarcinii de muncă. Datorită costurilor reduse și a mijloacelor existente extrem de precise, procesul de urmărire a ochilor este utilizat în dispozitive și aplicații pentru a creşte interacţiunea operator-computer și pentru a studia comportamentul uman în realizarea unor activități. Urmărirea ochilor este utilizată într-o gamă largă de aplicații, dar este aproape absentă în domeniul ingineriei (de exemplu, în cazul proceselor de producție). Cauza acestui fapt ar putea fi aceea că ingineria este o știință exactă, iar concepția produsului se bazează pe un set riguros de constrângeri fizice, funcționale și legale (realizarea proceselor tehnologice nu mai necesită alte criterii de evaluare, monitorizare sau control, față de prescripţiile tehnice stabilite în faza de concepţie a produsului și tehnologiei aferente realizării sale). Acest articol prezintă modul de utilizare a tehnicii de urmărire a ochilor în mediul de producție aferent industriei de automobile. În special, se va demonstra modul de utilizare a tehnicii pentru a optimiza asigurarea calității vopsirii caroseriei și fabricarea unor afişaje de tip head-up. Obiectivul cercetărilor realizate este de a examina ciclurile de asigurare a calității în ceea ce priveşte condițiile de muncă optimizate și calitatea îmbunătățită a producției.

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