# Blink and Wink Detection in a Real Working Environment

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Abstract: A simple and effective method of recognizing eye blinking in industrial conditions is presented. The developed method uses a camera built into safety glasses. The presented algorithm can be applied to recognize whether glasses are correctly put on – to check if employees use personal protective equipment. Recognition of open or closed eyes allows control by intentional winking. The algorithm uses only light sources present in the workplace and does not require infrared radiation (IR). The solution was tested on a set of 1797 eye photos recorded in a group of 10 participants. An analysis of the correctness of blink recognition and the correctness of the algorithm's operation in various lighting conditions was carried out. Experiments showed that the proposed algorithm met required project assumptions. The averaged results of blink recognition obtained using the developed method are: accuracy 96.5%, precision 93.8%, specificity 98.9% and sensitivity 84.9%. Additionally the algorithm is insensitive to changes in lighting and allows the use of one type of glasses for different employees.

## 1 INTRODUCTION

### 1.1 Motivation

Ensuring work safety is one of the most important tasks in industrial conditions. Eyes are particularly vulnerable to injuries. In industrial conditions, our eyes are exposed to many potentially dangerous factors: mechanical, chemical, biological and optical. The eyes can be protected by appropriate safety glasses or protective goggles. In selected conditions, full face protective gear can also be used. The use of personal protective equipment is strictly required (Bartkowiak, et al., 2012) in many workplaces. However, not in all of the required situations do employees use personal protective equipment (Workers Fail to Wear, 2011). Unfortunately, this happens often, despite restrictions. This is the result of low awareness of threats (despite training), individual negligence and disregard for regulations. A very important problem arises that should be solved: how to check whether an employee correctly uses his/her protective glasses. To check this, we can propose different sensors to measure the parameters (Kowalczyk and Sawicki, 2019). We can measure: distances between glasses and nearest surfaces; temperature in the environment of the glasses (looking for human body temperature); the color of the nearest surface (looking for skin color); and vibration (looking for heart rate). All these parameters can inform us as to whether glasses are correctly applied. However, this type of analysis is impractical – too many additional factors interfere with the correct assessment. As a result, it can only be performed in laboratory conditions, and not in industrial ones. It seems that an effective assessment could be made on the basis of eye image registration and blink recognition. For this, an effective algorithm for eye blink detection is required; an algorithm that can work in connection with safety glasses in industrial conditions.

On the other hand, work in industrial conditions is often supported by additional equipment. Computers, monitors or other displays can facilitate the work, can

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provide additional information, and give the possibility of additional control. However, the employee's hands are most often occupied with the activities being performed. In this situation, the best solution is a touchless interface using eye gestures, head gestures or other body language (Evans et al., 2000, Kim and Ryu, 2006). The use of eye gestures is not a new idea. Eye gesture, eye tracking and gaze tracking (oculography) can be used in many areas of human activity, including human-computer interaction (HCI) (Duchowski, 2007, Singh and Singh, 2012). A survey of eye blinking applications in HCI can be found in (Majaranta and Bulling, 2014, Singh and Singh, 2018). There are also many applications were a wearable technology is proposed for multimodal HCI. For example, a touchless computer control method based on analysis of head movement and eye gestures is presented in (Sawicki and Kowalczyk, 2018). This solution has been patented (Kowalczyk and Sawicki, 2017) and allows replacement of the standard mouse in effective way. A good solution for industrial environments would be to use eyeglasses to recognize eye gestures, because it would not limit the employee's movements in the workplace.

### 1.2 The Aim of the Article

A very important problem in industrial environment is to check whether an employee correctly uses protective glasses. Analysis of eye image would give the possibility to combine both functions considered here: safety glasses with the ability to control with the help of eye gestures and head movements. The key problem in this case is the correct and effective recognition of eye blinking for such an application. The main aim of this paper is to develop a simple and effective method that allows recognition of eye blinking in industrial conditions using sensors built into glasses.

## 2 BLINK DETECTION FOR EYE GESTURES: THE SHORT SURVEY OF SOLUTIONS

The most popular method for blinking detection is the visual analysis of a facial image. It is also the oldest method. When an image is captured using a camera, we can step by step recognize individual elements. In the first step, we isolate the face shape, in the second the eye region and individual eye parts. In the third step, we try to detect eye state: open or closed. in this way, blinking / winking can be detected. In the last step, various methods are applied. Most popular are those based on pupil detection (Kim et al., 2011). These methods include: statistical methods (Bacivarov et al., 2008), methods based on image comparison to templates (Grauman et al., 2001), use of principal component analysis (PCA) (Le and Liu, 2013), or use of median filter in shape analysis (Lee et al., 2010). The main disadvantages of these methods are their high sensitivity to changes in lighting conditions or to changes in the position of the camera relative to the eye pupil.

To solve the problem of the external lighting conditions, an additional source of infrared radiation (IR) is applied. In paper (Kapoor and Picard, 2001), IR LEDs and a proper IR camera allow analysis of an image independently of the lighting conditions. An effective method based on IR for blinking and winking detection is presented in (Kowalczyk and Sawicki, 2019). This method also includes a ready algorithm for replacing the mouse keys with eye gestures. There are also many interesting commercial solutions where eye blinking and/or gaze are recognized. A system of eye blinking detection using IR can be applied for communication by disabled people (Blink-It, 2018). Driver fatigue can also be recognized on the basis of blinking analysis (and IR LEDs and cameras): see (Kojima, 2001), and (Driver Monitoring Technology, 2018) for an idea and a commercial solution, respectively.

## 3 INDUSTRIAL CONDITIONS AND THE MAIN ASSUMPTIONS OF THE PROJECT

The use of an additional IR source and camera allows for practically error-free blink recognition (Kowalczyk and Sawicki, 2019). It is documented that infrared radiation with a wavelength greater than 1400 nm does not penetrate the retina of the eye (Wolska, 2013). Additionally, the emissions from the IR source should not exceed 100W/m$^2$ at the retinal level. It is assumed that IR radiation with such parameters is safe for the human eye (Wolska, 2013). However, even such low parameters are not accepted during continuous operation in industrial conditions. In industrial conditions, no IR source is accepted in close proximity to the eye. Therefore, we were looking for an algorithm that uses only light sources present at the workplace.

A camera that recognizes blinking will be placed close to the eye in the frame of the glasses. Thanks to this, typical errors in the interpretation of facial images are eliminated: the camera will register the correct image of the eye (always the same) although any position of the user's head and direction of the eyes in any direction is possible. It also does not matter if there is partial covering of the user's head or face; provided, of course, that the lighting is not be completely obscured. The algorithm we are looking for should meet the following conditions:

- The proposed algorithm should allow correct recognition of the eye state (closed or open); it means recognition of eye blinking as well as intentional winking.
- It should work correctly with any position of the pupil and gaze direction.
- It should work correctly at close distances between camera and eye. Cameras should be placed in the frame of a pair of glasses. It cannot obscure the wearer's field of vision. This means that a wide-angle lens will be used; it will be characterized by large distortions (perspective and non-linear). In this situation, we cannot expect, for example, that the pupil will have a round shape. Such an assumption is often adopted in the analysis of an eye image.
- The proposed algorithm should be insensitive to changes in lighting. In industrial conditions, good lighting of the workplace is required. However, there are different zones: lighter and darker (with a soft shadow). In addition, usually a lot of different light sources are mounted. This means that reflections (flashes) appear on the surface of the open eye.
- It should work correctly when use only light sources present at the workplace. The special sources of light (mounted LEDs), especially IR will not be allowed.
- The proposed algorithm should be as simple as possible and should work fast when applied on simple microcontroller. The application should work effectively in real time.

The adopted assumptions regarding distortions of the eye image are very important, they allow the use of one type of glasses (with a specific camera setting) with different employees. There will be no requirement for an initial calibration for each individual employee before starting work. On the other hand, such an assumption means that solutions similar to those used in eyeglasses with IR sources cannot be considered. That is, the use of the analysis of luminance levels at specific, precisely defined points of the image (e.g. along a specific image section) is not accepted.

# 4 ALGORITHM FOR EYE BLINK/WINK DETECTION

The proposed Algorithm is as follows:

```
A1. Download the RGB image from the
    camera.
A2. Convert the RGB image into a
    monochrome image (Image_Mono)
    with a relatively small resolution
    (about 600 x 400).
A3. Apply Gaussian blur to Image_Mono
    and determine Image_Gauss.
A4. Determine the differential image:
    Image_Diff =
       255 - Image_Mono + Image_Gauss.
A5. Apply thresholding and transform
    Image_Diff into binary
    form Image_Bin.
A6. Calculate the measure of detail MD.
    MD = the sum of all pixel values of
    Image_Bin.
A7. Test the closing / opening of the
    eye
    If MD > = MofOE,
       then the eye is closed.
    If MD  <  MofOE,
       then the eye is open.
```

Where **MofOE** is a Measure of the Open Eye. The value of this parameter was determined experimentally based on a series of photos taken for different people.

The algorithm uses the observation that the image of the closed eye in fact contains much less detail than the image of the open eye. In the image of the open eye, we can see many different elements: pupil, iris, whites, eyelids (independently lower and upper), and eyelashes. These elements and the boundaries of areas related to these elements (and differences in contrast between them) create a rich set of details. They are emphasized after subtracting the blurred image (**Image_Gauss**). On the other hand, the image of the closed eye is primarily a large area of the eyelids – the area in which the image of skin with a very similar color (gray level) dominates. This is an area without differences, borders, contrasts and details. In the image of the closed eye, we cannot see the elements of the eye; the only elements apart from the eyelids might be eyelashes, and possibly skin wrinkles at the corners of the eyes. Of course, in practice, the camera will not always capture the image of a perfectly closed eye. However, the state of eye during blinking (not completely closed) also differs significantly in terms of detail from the image of the open eye. The more closed the eye, the smaller the area of the elements of the open eye becomes – and the more the area of the eyelids dominates. Consecutive images corresponding to individual stages of the algorithm's implementation are presented in Figure 1.

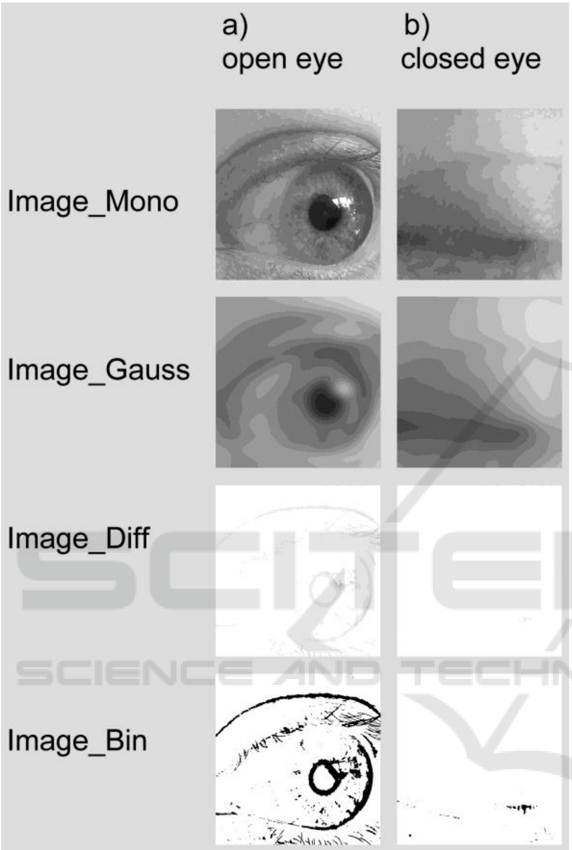


Figure 1: Images of eye in consecutive stages of proposed algorithm: a) open eye b) closed eye.

The Gaussian blur parameter (stDev = 20), the binarization threshold (0.95) and the change of the value of **MofOE** were experimentally determined based on a series of 15,000 photos taken for 10 different people. An example graph of the sum of pixel values (MD) of **Image_Bin** for one person is shown in Figure 2.

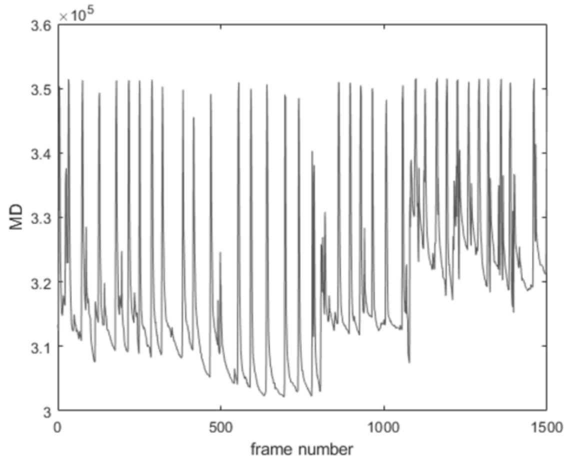


Figure 2: An MD chart for one person for subsequent registered images.

# 5 BLINK DETECTION FOR EYE MODEL OF GLASSES AND PERFORMED TESTS

## 5.1 The Model of Glasses

We have developed and manufactured a model for glasses. Original industrial safety glasses were used. We did not have a sufficiently small camera with a wide-angle lens. Therefore, we cut out the surface of one glass in the glasses, mounted the camera there and equipped it with an additional wide-angle lens (Figure 3). In this way, the camera is positioned close to the nose and covers the image of the entire eye from a very close distance. This corresponds to the situation of placing the microcamera in the frame of glasses in the target solution. The specific setting (at the corner of the eye), the small distance and the wide angle of the lens mean that the image of the eye can differ significantly from the typical image of the eye which we get by looking at the face from a sufficient distance ("full face" view).

## 5.2 Conducted Tests

We conducted tests using large set of photos. We have recorded 1797 images of eyes (closed and open) in experiment in which 10 participants took part: 3 women aged 40 to 50 (average age 45) and 7 men aged 29 to 55 (average age 40). Each participant blinked spontaneously (in a natural way) for 1 minute. The images were recorded by a camera attached to the frame of the glasses. The participants could move

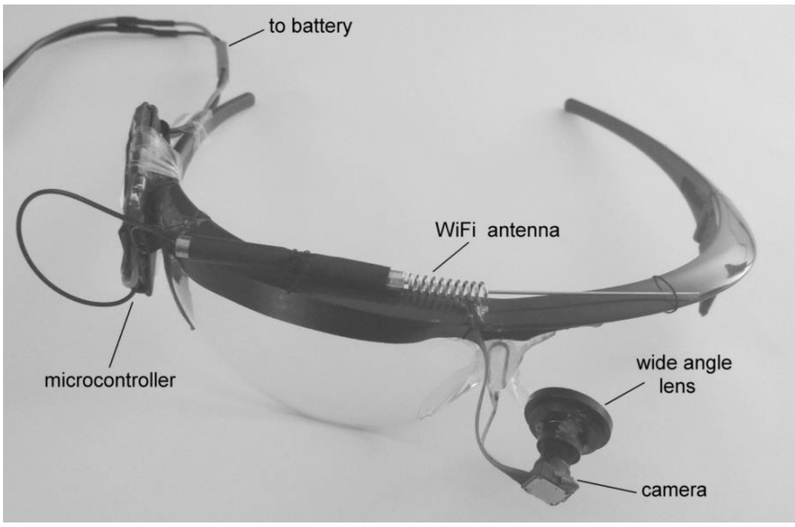


Figure 3: Prepared model of glasses used in our experiments.

Table 1: Results of tests True Positive (TP), False Negative (FN), True Negative (TN), False Positive (FP), Accuracy (ACC), Precision (PREC), Specificity (SPEC), Sensitivity (SENS).

| Participant | TP | FP | TN | FN | ACC | PREC | SPEC | SENS |
|---|---|---|---|---|---|---|---|---|
| 1. | 15 | 1 | 739 | 6 | 0.991 | 0.938 | 0.999 | 0.714 |
| 2. | 40 | 3 | 729 | 0 | 0.996 | 0.930 | 0.996 | 1.000 |
| 3. | 37 | 0 | 730 | 3 | 0.996 | 1.000 | 1.000 | 0.925 |
| 4. | 19 | 0 | 733 | 15 | 0.980 | 1.000 | 1.000 | 0.559 |
| 5. | 19 | 1 | 736 | 8 | 0.988 | 0.950 | 0.999 | 0.704 |
| 6. | 19 | 1 | 739 | 3 | 0.995 | 0.950 | 0.999 | 0.864 |
| 7. | 16 | 2 | 736 | 10 | 0.984 | 0.889 | 0.997 | 0.615 |
| 8. | 35 | 0 | 733 | 0 | 1.000 | 1.000 | 1.000 | 1.000 |
| 9. | 40 | 1 | 729 | 1 | 0.997 | 0.976 | 0.999 | 0.976 |
| 10. | 18 | 8 | 737 | 0 | 0.990 | 0.692 | 0.989 | 1.000 |
| All | 258 | 17 | 1476 | 46 | 0.965 | 0.938 | 0.989 | 0.849 |
| Mean | 25,8 | 1,7 | 733,95 | 4,6 | 0.992 | 0.932 | 0.998 | 0.836 |

their head. In this case, the camera changed its position according to the movements of the head and the image was registered correctly. On the other hand, movements of the head caused changes in the face lighting, resulting in images of the eye with slightly different histograms. However, the use of the proposed algorithm gave very similar final images (**Image_Bin**).

The images for analysis were pre-selected. As the blink detection algorithm was being tested, the test data should be unambiguous. Therefore, all images where state of the eye was ambiguous were deleted. A set of images was prepared for the analysis, on which the eye was correctly closed or correctly open.

## 5.3 Analysis of the Performed Tests

We carried out an analysis of the performed experiments. The results in the form of calculated parameters are presented in Table 1. True Positive (TP) means that the algorithm correctly recognized blinking – eye as closed. True Negative (TN) means that the algorithm correctly recognized the eye as open. False Positive (FP) means that the algorithm incorrectly recognized blinking (open eye recognized as closed). False Negative (FN) means that the algorithm incorrectly recognized an open eye (closed eye recognized as open).

Analyzing the results, it can be concluded that the algorithm recognized the state of the eye very well.

There were very few mistakes, as evidenced by the high values of the determined parameters in Table 1. We noticed an interesting position in Table 1. Participant 4. FN=15. She was a woman with heavy make-up. The shiny eyelid reflected lights and bright objects. This could be qualified as a large number of details, so the algorithm could recognize the eye as open. The only solution for this case is the hope that employees at the workplace do not use heavy make-up. An individualized threshold setting could help.

It is worth emphasizing the properties of the proposed algorithm. The properties that are consistent with the assumptions and that are relevant to the future application.

Experiments have shown that the algorithm is insensitive to camera settings. It is only important that the camera covers the image of the eye (smaller or larger, placed in the image in any position). The rotation of the camera is also irrelevant. The algorithm is not sensitive to the perspective projection method. This is very important, because the location of the camera in the corner of the glasses, very close to the eye, can cause large distortions.

The proposed algorithm is not sensitive to flashes appearing due to the reflection of light (or very bright objects) at the surface of the eye. What is more, the reaction to flashes becomes an advantage of this algorithm. In practice, flashes can arise only on the surface of an open eye – adding in this case further details. And the more details there are, the easier it is to recognize an open eye in the proposed algorithm. Similar reflections will be not created at the surface of the eyelid, which has light-scattering properties.

The algorithm is practically insensitive to the level of illumination. The Gaussian blur defines the average brightness level of the image. The details that remain after subtracting the blur have a level of brightness not much different from the average and at the same time are also dependent on the average level of brightness. We conducted an analysis of the experiment cases when the participant's face was illuminated in different ways. In addition, we conducted a series of experiments deliberately setting different levels and positions of lighting. The results of blink recognition were consistent with the results for the same participant in experiments carried out under typical/average (and also correct) lighting conditions. In 95% of cases the algorithm worked correctly. In other cases (5%) it was necessary to manually correct the threshold level. Experiments have shown that, for different levels of eye lighting, the brightness levels of **Image_Diff** images are very similar. This is consistent with the results described in article (Le et al., 2010), where thresholding was also used, but a median filter was applied.

# 6 THE NEW SOLUTION: APPLICATION APPROACH

There already exists a lot of systems in vehicles that analyze eye blink frequency to assess driver's fatigue. They are effectively used in vehicles where the position of the driver's head is fixed. But at workplaces in industry it doesn't happen. The proposed solution (camera built into the frame of glasses) solves the problem in any position of head and allows for effective use in industrial environments as well.

Industrial conditions place specific requirements on the working of a discussed algorithm. In addition, the algorithm is designed to analyze images from a camera built into the frame of a pair of glasses. This means additional conditions that result from the specific projection that occurs while recording images with a camera. A preliminary analysis of known solutions showed that it is very difficult to use pre-existing solutions. It is also difficult to match a known solution to the set requirements.

The proposed simple solution allows recognizing the blinking effectively. As a result, the eye state (closed or open) can be correctly analyzed. It is sufficient for effective diagnosis of fatigue (Caffier et al., 2003, Galley et al., 2004). Good results can be achieved by using PERCLOS parameter (Sommer and Golz, 2010). PERCLOS is defined as the percentage of time when the pupil is obscured by the eyelid to degree greater than 80% (Wierwille et al., 1994).

It is worth noting that no IR source is required in close proximity to the eye. This is very important in real, industrial conditions. The lack of IR source also distinguishes the proposed solution from many well-known methods, including patented one (Kowalczyk and Sawicki, 2017).

On the other hand, it seems that to check whether workers wear safety glasses, very simple methods can be used. For example tactile sensors to measure distance between frame of glasses and body. Unfortunately, these methods work properly only in ideal laboratory conditions and cannot be used in real industrial conditions (Kowalczyk and Sawicki, 2019). In addition, the analysis of eye blinking does not allow for any fraud attempt in practical situations.

# 7 CONCLUSIONS

The aim of the research was to develop a simple algorithm for eye state recognition working in industrial applications. A solution has been proposed based on the fact that many more details are shown in the image of an open eye than in an image of a closed eye. An algorithm was introduced in which Gaussian blur is applied. Then, using a differential comparison, an image is prepared in which the pixel values determine the measure of details for the image of the eye.

We have also built the model of the glasses in which the proposed algorithm was tested. The solution was tested on a large set of eye photos. The pictures were recorded in a group of 10 participants. The accuracy of eye state recognition was 96.5%. This was a very good result that allows for application in the assumed conditions. Experiments have shown that the proposed algorithm works correctly in conditions of changeable lighting. The algorithm also works correctly for the specific working conditions of the camera – position very close to the eye and application of a wide-angle lens. In this way, the required project assumptions have been met.

The algorithm allows correct recognition of the eye state (closed or open). This recognition is not affected by the opening time and closing time. Therefore, the algorithm allows the identification of spontaneous blinking as well as intentional winking. In this way, it can be applied to the applications that were considered: for recognition of whether glasses are correctly put on and for control by eye blinking.

In the future, we plan to try to extend the algorithm with the possibility of automatically adjusting the threshold (parameter **MofOE** – **Measure** of **the Open Eye**) – without experimental analysis on a large set of photos. We are also planning to use a special microcamera that will allow it to be built into the frame of the glasses.

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# REFERENCES

Bacivarov, I., Ionita, M., Corcoran, P., 2008. Statistical models of appearance for eye tracking and eye-blink detection and measurement. *IEEE Transactions on Consumer Electronics*. 54(3). 1312–1320. DOI: http://dx.doi.org/10.1109/TCE.2008.4637622.

Bartkowiak, G. et al., 2012. Use of Personal Protective Equipment in the Workplace. In: *Handbook of Human Factors and Ergonomics*, fourth ed. John Wiley & Sons, Inc. DOI: http://dx.doi.org/10.1002/9781118131350.ch30

Blink-It – system for environment control and communication for entirly disabled people. http://www.ober-consulting.com/13/lang/1/ last accessed 20 December 2018.

Caffier, P., Erdmann, U., Ullsperger, P., 2003. Experimental evaluation of eyeblink parameters as a drowsiness measure. *European Journal of Applied Physiology*, 89(3/4), May 2003, 319-325. DOI: http://dx.doi.org/10.1007/s00421-003-0807-5

Driver Monitoring Technology. In: Automotive, World's best driver monitoring technology that enhances safety in real time. https://www.seeingmachines.com/industry-applications/automotive/ last accessed 20 December 2018.

Duchowski, A., 2007. *Eye tracking methodology. Theory and practice*. sec. ed. Londyn: Springer.

Evans, D.G., Drew, R., Blenkhorn, P., 2000. Controlling Mouse Pointer Position Using an Infrared Head-Operated Joystick. *IEEE Transactions on Rehabilitation Engineering*, 8(1), 107–117.

Galley, N., Schleicher, R., Galley, L., 2004. Blink parameter as indicators of driver's sleepiness – Possibilities and limitations. *Vision in Vehicles*, 10, 189-196.

Grauman, K., Betke, M., Gips, J., Bradski, G., 2001. Communication via eye blinks - detection and duration analysis in real time. In: *Proc. of IEEE CVPR*, Kauai, HI, USA. 2001, pp. 1010–1017, DOI: http://dx.doi.org/10.1109/CVPR.2001.990641.

Kapoor, A., Picard, R.W., 2001. A real-time head nod and shake detector. In: *Proc. 2001 Workshop on perceptive user interfaces*. November 2001. pp. 1-5. DOI: http://dx.doi.org/10.1145/971478.971509.

Kim H., Ryu D., 2006. Computer control by tracking head movements for the disabled. In: *Proc. of the ICCHP '06*. In: *Lecture Notes in Computer Science*, 4061, pp.709–715, Springer.

Kim, D., Choi, S., Choi, J., Shin, H., Sohn, K. 2011. Visual fatigue monitoring system based on eye-movement and eye-blink detection. In: *Proc. SPIE 7863, Stereoscopic Displays and Applications* XXII, 786303. DOI: http://dx.doi.org/10.1117/12.873354.

Kojima, N., Kozuka, K., Nakano, T., Yamamoto, S. 2001. Detection of consciousness degradation and concentration of a driver for friendly information service. In: *Proc. of the IEEE International Vehicle Electronics Conference*, Tottori, Japan. pp. 31-36. DOI: http://dx.doi.org/10.1109/IVEC.2001.961722.

Kowalczyk, P., Sawicki, D., 2017. Computer controlling device, (in Polish: Urządzenie do sterowania komputera), *Patent Number PL402798*, granted on 7 June 2017, by Polish Patent Office.

Kowalczyk, P., Sawicki, D., 2019. Blink and wink detection as a control tool in multimodal interaction. *Multimedia Tools and Applications*. 78(10), 13749–13765. DOI: http://dx.doi.org/10.1007/s11042-018-6554-8.

Lee, W.O., Lee, E.C., Park, K.R., 2010. Blink detection robust to various facial poses. *Journal of Neuroscience Methods*. 193(2), 356–372.

Le, H., Dang, T., Liu, F., (2013). Eye blink detection for smart glasses. In: *Proc. of 2013 IEEE International Symposium on Multimedia*. pp.305-308. DOI: http://dx.doi.org/10.1109/ISM.2013.59

Majaranta, P., Bulling, A., 2014. Eye Tracking and Eye-Based Human–Computer Interaction. In: Fairclough, S., Gilleade, K. (eds) *Advances in Physiological Computing. Human–Computer Interaction Series*. pp. 39-65. Springer. DOI: http://dx.doi.org/10.1007/978-1-4471-6392-3_3

Sawicki, D., Kowalczyk, P., 2018. Head Movement Based Interaction in Mobility. *International Journal of Human–Computer Interaction*. 34(7), 653-665. DOI: http://dx.doi.org/10.1080/10447318.2017.1392078.

Singh, H., Singh, J. 2012. Human eye tracking and related issues: a review. *International Journal of Scientific and Research Publications*. 2(9), 1-9.

Singh, H., Singh, J., 2018. Real-time eye blink and wink detection for object selection in HCI systems. *Journal on Multimodal User Interfaces*, 12(1), 55-65. DOI: http://dx.doi.org/10.1007/s12193-018-0261-7

Sommer, D., Golz, M., 2010. Evaluation of PERCLOS based Current Fatigue Monitoring Technologies. In: *Proc. of the 32nd Annual International Conference of the IEEE EMBS*, Buenos Aires, Argentina, August 31 - September 4, 2010, DOI: http://dx.doi.org/10.1109/IEMBS.2010.5625960

Wierwille W, Wreggit, S.S., Kirn, C.L., Ellsworth, L.A., Fairbanks, R.J., 1994. Research on vehicle-based driver status / performance monitoring: development, validation, and refinement of algorithms for detection of driver drowsiness. Report No DOT HS 808 247. NHTSA, Washington D.C. https://catalog.hathitrust.org/Record/005519249 last accessed 01 August 2019.

Wolska, A., 2013. Artificial optical radiation – principles of occupational risk assessment (in Polish). Central Institute for Labour Protection - National Research Institute, Warsaw Poland.

Workers Fail to Wear Required Personal Protection Equipment. In: Sustainable Plant, By Objective. http://www.sustainableplant.com/2011/07/workers-fail-to-wear-required-personal-protection-equipment/ last accessed 20 December 2017.