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A Study on Tiredness Assessment by Using Eye Blink Detection

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ABSTRACT

In this paper, the loss of attention of automotive drivers is studied by using eye blink detection. Facial landmark detection for detecting eye is explored. Afterward, eye blink is detected using Eye Aspect Ratio. By comparing the time of eye closure to a particular period, the driver's tiredness is decided. The total number of eye blinks in a minute is counted to detect drowsiness. Calculation of total eye blinks in a minute for the driver is done, then compared it with a known standard value. If any of the above conditions fulfills, the system decides the driver is unconscious. A total of 120 samples were taken by placing the light source front, back, and side. There were 40 samples for each position of the light source. The maximum error rate occurred when the light source was placed back with a 15% error rate. The best scenario was 7.5% error rate where the light source was placed front side. The eye blinking process gave an average error of 11.67% depending on the various position of the light source. Another 120 samples were taken at a different time of the day for calculating total eye blink in a minute. The maximum number of blinks was in the morning with an average blink rate of 5.78 per minute, and the lowest number of blink rate was in midnight with 3.33% blink rate. The system performed satisfactorily and achieved the eye blink pattern with 92.7% accuracy.

Keywords: Facial Landmarks; Eye Closure Time; Eye Blinks; Eye Aspect Ratio (EAR); Blinks per Minute

INTRODUCTION

The transport system is an integral part of human activities nowadays. Everyone can be a victim of unconsciousness and drowsiness during driving. Unconsciousness can affect especially after a short sleep, impaired physical condition or during long journeys. Driver's level of vigilance is reduced by the perception of sleep, which produces a dangerous condition and increases the probability of happening of road accidents. The loss of attention to the driving of the drivers is found to be the major issue of devastating road accidents. And this rate of accidents can be reduced by avoiding the unconscious situation of the drivers.

Onboard monitoring of the automotive driver is necessary to reduce the rate of accidents. However, there are many processes to determine if one is attentive to something or not. On the opposite hand, an outsized range of road accidents occurs as a result of the motive force temporary state. Thus within the field of active safety analysis, developing a system for measuring driver's alertness level is changing into a major issue (Wang et al. 2006). There are various approaches to detect consciousness of a driver. Some important approaches are presented below:

Steering Pattern Monitoring: Analyzing steering-wheel movements for detection of fatigue and drowsiness is a well-documented process. The main advantages of this process are cost-effectiveness, continuous and non-intrusive working even under extreme environmental condition.

Vehicle Position in Lane Monitoring: This process continuously monitors vehicle position in the lane using cameras. Cameras are positioned downward to trace the wheel and lane lines. The captured image is processed to decide the vehicle position. The process can warn a driver for enhancing driving safety.

Driver Eye/Face Monitoring: This process requires a camera to continuously capture the image of the face of the driver. Several portions of the face can be used to detect consciousness level. Analyzing eye blink rate, eye aspect ratio, eye closure time, etc. are some popular methods. This kind of system can warn if the observed result is anomalous to the prescribed value.

Physiological Measurements: This process requires a different kind of sensors. Brain activity, skin conductance, muscle activity, heart rate, etc. are measured using a sensor. The measured values are compared with the values of a drowsy person. This kind of system is costly and complicated.

Consciousness detection using computer vision technology is an old field. From time to time many works have been done in this field. There are some lacking in the previous works. There is no significant use of this technology among the drivers and almost no drivers know about such an existing system.

We covered some important methods of working with eye movement and gaze tracking. Our covered topics specially included eye blink systems and applications. Driver assisting system (DAISY) is a driver helping system. This system works as an observation and warning assistant for the driver. DAISY is currently used in German motorways (Onken 2014). But this system does not identify if the driver is conscious or not. This system only assists the distracted driver in reducing accident. Android mobile phone-based eye-blink detection method is studied by Noman and Ahad (Noman & Ahad 2018; Ahad and Noman 2019). It is a real-time system to do gaze tracking and eye-blink detection. A face recognition-based surveillance system is proposed where faces are detected and then processed by the Viola-Jones method (Mahdi et al. 2017). Video-based surveillance is explored where suspicious loitering is detected (Shahad et al. 2018).

Singh and Papanikolopoulos proposed a noninvasive vision-based system for detecting drowsiness level in drivers (Singh and Papanikolopoulos 2006). This system only identifies a driver's short time of sleep using eye closure time. A driver can be unconscious by not keeping the eye closed for a significant time. Ji et al proposed a real-time online example in (Ji et al. 2004). Their system used remotely placed charge-coupled device cameras which were prepared with active infrared illuminators for driver fatigue monitoring. They consider head movement, gaze movement, lid movement, and facial expression of the driver to measure the level of alertness. By using PERCLOS and AECS they have compared sleepiness detection. They did not consider eye blink an eye blink is one of the best ways of determining fatigue. A copilot (Ayoob et al. 2003) is an unconscious driver monitor system. Copilot has been developed by the Robotics Institute in Carnegie Mellon University, USA. Copilot is a video-based system which estimates PERCLOS.

A real-time eye tracking using USB camera which also supported eye blink detection was planned by Chau and Betke (Chau & Betke 2005). Their planned system was comprised of a template matching approach for finding eyes and detect eye blinks. Their proposed system was 95.3% accurate in detecting blink. This system can separate open and closed states. The same system was performed using a USB camera (Magee et al. 2000). They implemented a multi-scale template correlation on their system. After tracking the face, they analyzed the right and left eye for deciding if the computer operator is looking on camera. They controlled computer programs using detected eye direction. Blink Link and Eyebrow Clicker were proposed by Gruman et al. (Elahi et al. 2013). Those are two video-based human-computer interaction tools. Blink Link can detect eye and measure the duration of the user. They ignored short blinks and used long blinks for a mouse click. They used 'Blink Patterns' in this system. Eyebrow clicker automatically triggers mouse click upon raising the level of the user's eyebrow. Eye Tribe tracker (Hansen et al. 2010) is a primarily affordable eye tracker that exactly determines the on-screen gaze position. It conjointly permits interact devices with the individual by blinking. Carsafe is an app that detects and alerts any distracted and tired driver using a rear-facing camera which implements computer vision and machine learning algorithm (You et al. 2013).

Rahman et al. (2015) proposed a method using eye blink monitoring. Their algorithm determines an open or closed state and activates an alarm when the driver is drowsy. But this method only works well under good lighting condition. A drowsiness detection system using eye blink patterns which detects visual changes in the location of the eye by horizontal symmetry feature had been proposed by Danisman et al. (2010). In this method, the accuracy rate decreases under high illumination condition. Facial landmarks are explored for fatigue detection (Irtija et al. 2018). In this case, a dataset is created from some images, instead of videos – from extended Cohn-Kanade dataset and Physiological Image Collection at Stirling (PICS). There were two categories of images: normal faces, and fatigued/tired faces. The results are good but on a limited dataset that should be more realistic. Also the accuracy is not excellent. In another direction, various faces are scanned and eye's locations or points on the screens are studied to decipher the autism level of different children (Syeda et al. 2017). In this research, Tobii eye-tracker is exploited. This concept can be incorporated for a driver's attention study in the future.

The systems are not perfectly self-dependent and error-free. The success rate in different lighting condition is still challenging. The different system works in a different way and a different algorithm. If we can integrate all the systems which required almost the same components to install, it would be more error-free. The installation process is complex and requires many components. Most of the time, the drivers find the installation process boring and cumbersome thus loses their interest. Total eye blink in a minute is also another important factor to decide the tiredness of a driver. There are no noteworthy systems which detect tiredness based on the total tiredness per minute.

Apart from various approaches related to face detection, eye gaze understanding, etc., various sensor-based and video-based activity recognition approaches can be explored (Ahad 2011; Ahad 2012). LoRaWAN sensors are explored for activity understanding in healthcare sectors (Hossain et al. 2018), however, these sensors can be used for driver's drowsiness and attention assessment.

The paper is organized as follows: Section 1 covers the background of the paper. In Section 2, the method to determine the tiredness is explored. Then, the results are presented in Section 3. Finally, the paper is concluded in Section 4.

METHODOLOGY

The system integrates eye closure time and total eye blink in a minute. To detect tiredness, detection of the eye is crucial. Then it compares the eye closure time to decide if the eyes are closed. The ratio of height to width of an eye are different for open eyes and closed eyes. This ratio is defined as the Eye Aspect Ratio (EAR). By using EAR open eyes and closed eyes can be differentiated. The whole process can be demonstrated in Figure 1.

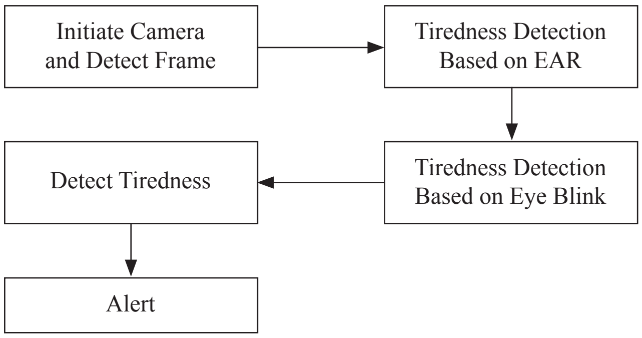

FIGURE 1. A simple flow diagram of the system

The flowchart of the proposed system is given in Figure 2. From the flowchart, some steps can be deduced. In the first step, it reads the frame from the webcam, searches for face and detects the eye. Face detection is done by the Viola-Jones face detection method (Viola & Jones 2001; Paul et al. 2018). If it finds the eye then, it will calculate EAR and compare it with a predefined value. In step 3: If the preceding step returns 'YES, it checks the eye closure time and total blink per minute. It will alert if any one of the condition is true. In the final step: When eye closure time does not exceed a predefined value, it returns the process to the initial step.

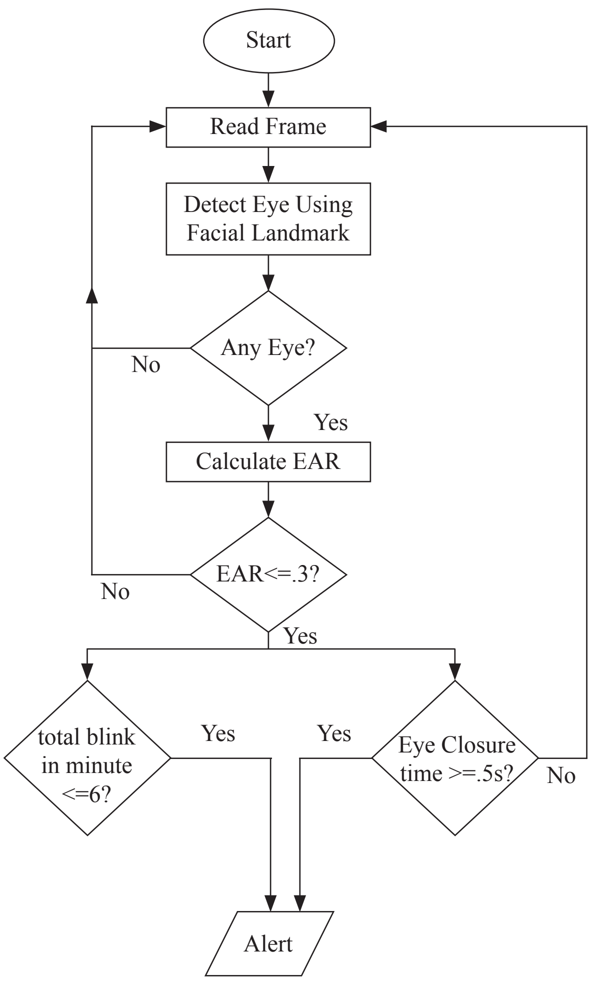

FIGURE 2. Flowchart of the system

The work has been segmented into taking an image from a live video webcam, detecting eye using landmarks, processing of ROI, blink detection and alert. The program starts with recording video. Then it separates each frame for processing. If there is no image it starts monitoring for changes in the image.

Drowsiness detection based on eye closure time: Facial landmark detection is a two-step process. First, it locates the face in the image and then detects the key facial structures on the face ROI (Soukupova & Cech 2016).

To detect the face in the image, the actual algorithm does not matter in each case. Face bounding box containing face is needed for this work. The face bounding box can be availed in several methods. Deep learning-based algorithms, OpenCV's Haar Cascades or pre-trained Hog and Linear SVM object detector can be used for getting the face bounding box (Soukupova & Cech 2016). Next, in the face region of the face bounding box, the key facial structures can be detected. Some methods of facial landmark detection are available. Almost every method try to label and detect Right eyebrow, Right eye, Left eyebrow, Left eye, Nose and Jaw (Soukupova & Cech 2016). The proposed system localizes only the right eye as one does not keep one eye closed and another eye open usually.

There are 6 coordinates (as shown in Figure 3). Those coordinates represent each eye starting from the left corner of the eye and then going clockwise around the remaining region.

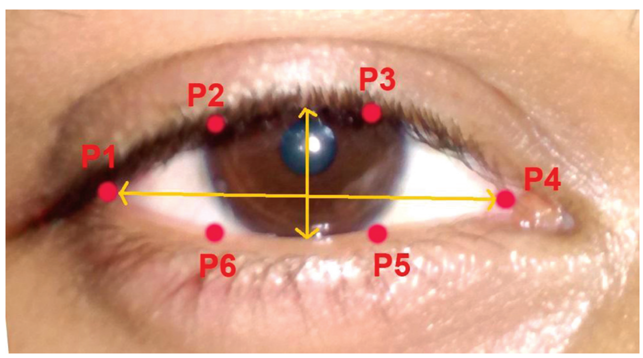

FIGURE 3. Demonstration of six coordinates of an eye, shown as and *P*1, *P*2, *P*3, *P*4, *P*5 and *P*6

A relation is found between the height and width of the coordinates. Soukupova and Cech had worked on real-time eye blink detection using facial landmarks. According to their work (Soukupova & Cech 2016), an equation can be derived which reflects a relation called Eye Aspect Ratio. The equation has been given below:

$$EAR = \frac{\|P2 - P6\| + \|P3 - P5\|}{2\|P1 - P4\|} \tag{1}$$

where, *P*1, *P*2, *P*3, *P*4, *P*5 and *P*6 are facial landmark locations in two-dimension. The numerator of the above equation determines the distance between the vertical eye.

And the denominator of the above equation determines the distance between the horizontal eye. Usually, when a blink occurs, the value of the *EAR* will become close to zero. Then the value of *EAR* for consecutive three frames are recorded. In accordance with the Harvard Database of Useful Biological Numbers, the average duration for a single is 0.1 to 0.4 seconds or 100 to 400 milliseconds for the human eye (B10NUMB3R5 2019). Eye closure and blink definition are different from one another. When the duration of eye blink is more than one second, it is considered as an eye closure. The eye closure is a blink with duration more than 0.5 seconds (Svensson 2004). If the value of *EAR* remains less than 0.3 for 5ms, it is considered that the driver is tired.

Drowsiness detection based on eye blink rate: Based on the study (Asma-Ul-Husna et al. 2014), a total eye blink of a tired person is different from a normal person. When a person is in the drowsy state, the total number of eye blinks in a minute decreases. The average blink rate for a normal person is 10 blinks per minute and the number is 4-6 for a drowsy person. The total number of blinks in a minute has been stored. When the number of blinks decreases to 6 per minute, the system decides that the person is drowsy. As the total number of blinks in minute depends on the time of the day, total blink number has been compared with the corresponding blink number at a different time of the day.

RESULTS AND DISCUSSION

For the analysis of the result, this section is divided into two categories (according to the experimental setup). Tiredness detection based on (a) Eye closure time; and (b) Eyeblink rate. 40 samples had been taken in lighting condition for detecting tiredness for every setup based on pixel computation. The same experiment can be done at night by using an IR camera (Park et al. 2006). The illumination compensation algorithm had been used to detect eye blink. This method is 98.39 percent accurate in eye blink detection.

METHOD USING EYE CLOSURE TIME:

The overall result was satisfactory in a lighting condition. The system faced no problems in detecting eye. In poor lighting condition, the value of reduces thus it causes some errors.

FIGURE 4. Samples of computations of eye closure time

In this experiment, the system took the camera in different lighting conditions. At first, the face of the person was illuminated with light from the front, which is the most ideal case. There were 3 errors out of 40 samples, which gave 7.5 percentage errors. Then the illumination from the back and side of the person had been done. In that case, there were 6 errors and 5 errors respectively. Both gave 15 and 12.5 percentage errors respectively. The whole result is shown in Table 1.

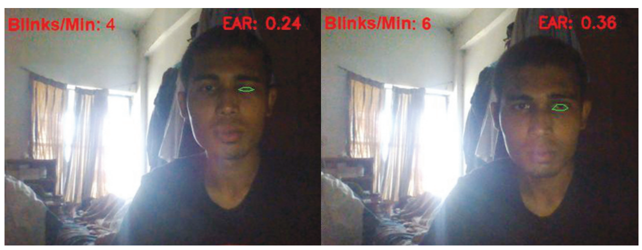

FIGURE 5. Samples of calculating blinks per minute

TABLE 1. Error rates at different lighting conditions

Category	Samples	Errors	% of error
Light from front	40	3	7.5
Light from back	40	6	15
Light from side	40	5	12.5

TABLE 2. Number of blinks at different time

Time Period	Samples	Average no. of blinks/min
Morning (8.00 am to 10.00 am)	40	5.78
Evening (5.00 pm to 7.00 pm)	40	5.10
Midnight (11.00 pm to 1.00 am)	40	3.33

METHOD USING EYE BLINK PER MINUTE:

At the various time of day, 40 samples had been taken. The total blink in a day is different from total blink at night for a drowsy person. Figure 5 shows two sample situations. In the morning the blink rate in a minute was around 5.78. When the same experiment is performed in the evening, the average number of blinks was reduced to 5.10 per minute. And the maximum drowsiness happened at midnight with the average number of blinks at 3.33 per minute. The number of blinks per minute for four different persons at a different time is shown in Figure 6.

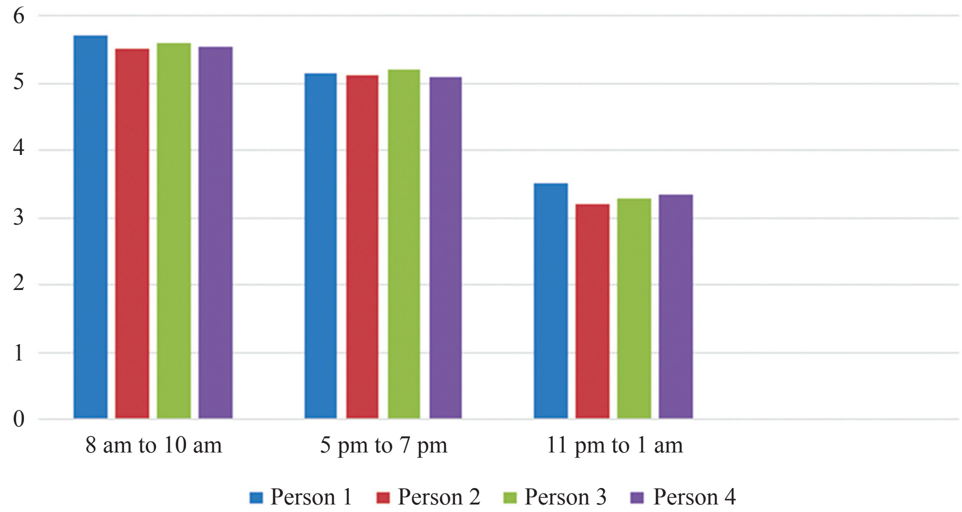

FIGURE 6. Blink frequency at different periods

A comparison of the different conventional methods of detecting drowsiness and our system is presented in Table 3. Our system is 9.5% more accurate than the Dual Camera-based system and 1.8% more accurate than the Eye Blink Pattern-based system. However, our system gives 1.5% less accuracy than the Eye Blink Monitoring-based system.

TABLE 3. Comparison with some conventional methods

Approach	Accuracy	Error Rate
Dual-camera System (You et al. 2013)	83.0%	17.0%
Eye Blinks Monitoring (Rahman et al. 2015)	94.0%	6.0%
Eye Blink Patterns (Danisman et al. 2010)	90.7%	9.3%
Our Approach	92.5%	7.5%

CONCLUSIONS

A major concern of this paper is to build an automatic system that can detect consciousness of the driver. It can be developed using a simple human-computer interaction using a single camera. In this paper, consciousness has been detected using two different methods, eye closure time and total eye blink per minute based on the facial landmark. Eye closure time was used to compare with a standard value in normal physical condition. The total eye blink per minute was recorded then compared according to the different time of day. If any of the above methods is unsatisfied then the system decides the driver is unconscious. The results were satisfactory. There were 7.5%-15.0% errors in different lighting conditions on eye closure time measurement. The error rate is less than some existing system. And the total eye blink per minute resembles with the standard eye blink rate of a tired person. The percentage of error can be decreased using a better camera. The main advantage of this system is portability, cost-efficiency, and feasibility over the existing system.

In the future, we look forward to integrating this system into an android app to make it easily accessible for all. Then the complexity of implementation will be alleviated and it will be portable. There will be some complexity in detecting blink at night using android as IR camera is not used. In that situation, a portable IR camera will be added. The improved system will also detect and alert on the situation when a driver uses mobile phones. A lot of drivers use a mobile phone during driving. This is one of the main factors of losing consciousness of drivers. We are planning to make a system to detect if the driver is talking to someone over the phone and coalesce it with the proposed system.

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