Real-Time Driver Awareness Detection System

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Abstract. Nowadays, drowsiness is the major reason for many road accidents. Due to this fact, different attempts have been made to successfully detect fatigue. In this paper, a computer vision method has been presented to determine the presence of fatigue in a driver’s face. A way for fatigue recognition through the exploitation of facial features has been proposed. A landmark algorithm has been used to find the marks of the eye edge and then calculate Eye Aspect Ratio (EAR), which is the main threshold parameter to judge whether the driver is sleeping or not. A new approach has been proposed to calculate EAR, which gives more accurate results than the common method. The results illustrate that the proposed method gives maximum detection fluctuation of (0.18), while the common method gives (0.33) detection fluctuation, the proposed system gives robustness against noise, so it can detect face and gives a decision for driver awareness with a noise level of (130) dB. An OpenCV library for image processing and Dlib library for feature extraction with the python IDLE has been utilized.

Keyword: Driver drowsiness detection, eye blinking, Eye Aspect Ratio (EAR), OpenCV, Eye detection

1. Introduction:

According to the latest statement from the World Health Organization (WHO) report in 2016, it is estimated that in 2013, 1.25 million people were killed on the roads worldwide. In addition to road deaths, there are up to 50 million people suffering from Non-fatal injuries each year as a result of traffic accidents, while additional indirect health consequences associated with this growing epidemic. The number of road traffic injuries is currently estimated is the ninth leading cause of death in all age groups worldwide, and is expected to become the seventh leading cause of death by 2030 [1].

The driver who sleeps on the steering wheel loses control of the vehicle, a procedure that often leads to traffic accidents. In order to prevent these devastating incidents, driver awareness should be guaranteed to prevent drowsiness. In the last decade, various techniques have been used to detect driver drowsiness and can be broadly divided into three main categories [3]. The first category includes methods based on biomedical signals, such as cerebral, musculoskeletal, cardiovascular and vascular activity [4, 5, 6]. Typically, these methods usually require electrodes
connected to the driver's body, which often causes discomfort to the driver [7]. The second
category includes Vehicle-based measures - There are a number of metrics, wheel movement,
acceleration pedal pressure, etc., are constantly monitored and any change in these points exceeds
the limit to a large extent Increase the likelihood that the driver will be sleepy [8, 9]. The
advantage of these methods is that the signal is meaningful and that getting the signal is very easy.
The third category includes methods based on driver’s behavior including yawning, eye blinking,
eye closure, head appearance, etc. using image processing techniques, it is monitored through the
camera and the driver is alerted if any of these symptoms of drowsiness are detected [10,11].

2. Related work:
The camera is usually installed inside the car to understand the possible causes of car accidents.
This camera can also be used to detect driver fatigue. Several studies on fatigue detection are
described as follows.
Sharma et al. [15] used the number of pixels in the eye image to determine the state of the eye,
open or close. Wenhui Dong [22] suggested a way to detect the distance of the eyelid, then judge
the driver's condition through this type of information. Hornget at. [17] Created an edge map to
locate the eyes the eye condition is determined based on the HSL color space of the eye image.
This method accuracy depends on the location of the eyes. Liu et al. [18] Suggested ways to detect
upper and lower eyelids based on the edge map. The distance between the upper and lower eyelids
is then used to analyze the eye condition. Besides, Dong et al. [20] Suggested methods through the
use of Active Appearance Model (AAM) to locate the eyes. After that, Percentage of eye Closure
(PERCLO) was calculated to detect fatigue. For the above methods, the determination of eye areas
was easily affected by changing the brightness. Qiang Ji [23] relied on IR illumination to locate
the eyes. and Yin et al. [19] used Gabor filters to obtain a multi-size representation of image
sequences and Local Binary Patterns(LBP) are extracted from each multi-scale image. Nikolaos P
[21] uses front view and lateral view Images to identify the eyes accurately.

Always, the eyes have two kinds of information: opening the size and duration of different cases.
By analyzing the rules of eye change in fatigue, an effective way to detect driver fatigue has been
suggested.

3. Detection procedure
The discovery of drowsiness is directly related to the eye blink detection component. The eye
blink is fast closing and re-opening the human eye. Everyone has a slightly different pattern of
blinks. The pattern varies in the speed of closing and opening, in terms of pressure on the eye and
blink duration. The eye blink lasts about 100-400 milliseconds.
Shape predictor_68_Facial Landmark detection is used to predict the eye region.
Figure (1) shows the sleepiness which is measured by calculating the Eye Aspect Ratio (EAR)
(Euclidean distance between the eyelids are calculated). The eye landmarks are located for every
video sequence; the aspect ratio is adjusted between the width and height of the eye.

\[
EAR = \frac{||p_2 - p_6|| + ||p_3 - p_5||}{2 ||p_1 - p_4||}
\]
$P_i$ where $i=1,2,3,4,5,6$ are the two-dimensional landmark location. Mostly EAR is fixed when
the eye is open and rapidly reduced for a blink (close to zero) when the eye is not in open state.
Because the eye blinking is done by both eyes simultaneously, the EAR of both eyes is averaged. If
it turns out that the person who watches the camera continuously, the Eye Aspect Ratio (EAR) is
normal and its value reaches low when the eye closes for a longer time. When the lower value is
reached, then drowsiness is detected.

3.1 Abbreviations and Acronyms

3.1.1 Euclidean distance $(d)$. It is the distance of the straight line between any two points in the
Cartesian or Euclidean space [13].

$$d(x, y) = d(y, x) = ((x_1 - y_1)^2 + (x_2 - y_2)^2 + \ldots + (x_n - y_n)^2)^{1/2}$$

$$= (\sum_{i=1}^{n}(x_i - y_i)^2)^{1/2}$$

3.1.2 Eye Aspect Ratio (EAR). It is defined as the ratio between the height and the width of
the eye contour

Figure 1: eyes pattern detected automatically by [16]. The EAR is calculated
for many frames of a video. A single blink is represented.

Figure 2: the eye with its reference coordination points

A and B calculates the vertical distance of the eye and C computes the horizontal dimensions of
the eye:

$$\text{EAR} = (A + B) / (2.0 \times C)$$

3.1.3 Eye Threshold ($\text{T}_{\text{eye}}$). This is the threshold value for EAR. If the EAR in a frame is less than
this value, the eye is considered closed.
Eye state = \begin{cases} \text{open}, & \text{EAR} \geq T_{\text{eye}} \\ \text{closed}, & \text{EAR} < T_{\text{eye}} \end{cases} \tag{5}

\begin{equation}
T_{\text{eye}} \text{ value is determined by trial and error, check the different } T_{\text{eye}} \text{ values so that the system is able to correctly classify an instance of the open or closed eyes. By this method, we got the optimum value for } T_{\text{eye}} \text{ as }
T_{\text{eye}} = 0.25 \tag{6}
\end{equation}

4. Methodology
The main objective is to detect the drowsiness of the driver. It can be done in different ways such as detecting the driver’s facial expression and measuring the Eye Aspect Ratio (EAR). The blinking pattern is different for each and every individual. The pattern is different in terms of blink duration, fast closing and eye-opening [12]. Therefore, we proposed a drowsy detection method based on changes in the eye region using facial landmark points. The proposed method is summarized in Figure (2).

Figure 3: A scheme of the proposed drowsiness detection

Step1: the video is captured in real-time from the camera Installed in front of the driver’s face
Step2: extracting frames from the video.

Figure 4: Facial Landmarks point
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Step3: detecting face and landmark coordinates from each frame. This work has used the face detector, which is a collection of HOG features, a linear classifier, an image pyramid and moving window detection using the Dlib library [2]. To find the landmarks on the detected faces, the shape estimator tool is used that is provided in the Dlib library, this estimator gives 68 landmark points including the regions of jaw, eyes, eyebrows, mouth, and the tip of the nose (Figure (4)). After detection, the Landmarks are converted to coordinates(x, y).

Step4: after the face and eye region are predicted in the detection face, drowsiness can be measured by calculating the Eye Aspect Ratio (EAR) (Euclidean distance between the eyes are calculated), then EAR value of the eye is compared with the threshold values. If the EAR is lower than the threshold for a specified number of consecutive frames then the person is considered to be drowsy, else not.

5. **System implementation:**
The software implementation of the system is done by using Dlib [14] C++ library with the python IDLE. In order to start the implementation of the program, it will import the following libraries such as numpy, OpenCV, math, winsound, and matplotlib. The hardware implantation of the system is as shown in figure (5).

![Figure 5: Drowsiness Detection algorithm](image)

6. **System model**
A new approach has been proposed to calculate the EAR. This formula is cleared as follows:
1. the center top point and center bottom point have been calculated as the midpoint between
   $p_2$ and $p_3$, $p_5$ and $p_6$ respectively
   
   $p_1 = (x_1, y_1)$  
   $p_2 = (x_2, y_2)$  
   
   Midpoint $(p_1,p_2) = ((x_1 + x_2)/2, (y_1 + y_2)/2)$
   
   Center top point = Midpoint $(p_2,p_3)$
   
   Center bottom point = Midpoint $(p_5,p_6)$

2. The vertical height has been calculated as the distance between the center top point to the center bottom point:
   
   Vertical line length = $d$ (Center top point, Center bottom point)

3. The horizontal length has been calculated as the distance from $p_1$ to $p_4$:
   
   Horizontal line length = $d$ ($p_1$,$p_4$)

4. Finally, the EAR has been calculated as a ratio between Vertical line length and Horizontal line length elevation
   
   EAR = Vertical line length / Horizontal line length

7. The proposed system results.
   The driver fatigue detection system has been tested in different conditions and may be encountered by the driver in real-time. Including the factors that have been taken into account in formulating the test, conditions are
   
   1. Lighting: Day time.
   2. Appearance: With glasses, sunglasses, night glasses and without glasses
   3. Noise: detection with noise.

The average image capture rate during the test was 30 Frames Per Second (FPS). A computer with the properties as shown in table (1) below was used to test the proposed system:

| OPERATING SYSTEM | Windows 10 pro |
|------------------|----------------|

Figure 6: the eye with its reference coordination and the center top and bottom points
7.1 The EAR fluctuation detection over time

Figures (7) and (8) show the actual values of EAR for the left eye over time that have been obtained using the proposed and the common approaches respectively. Tables(2) and (3) show the actual values of EAR fluctuation detection for the left eye over time. Some of the Notes that can be made from the results: the minimum value for the EAR fluctuation detection is (0.18) and the maximum is (0.30) for the common approach. While for the proposed approach, the minimum value of the EAR fluctuation detection is (0.06) and (0.18) for the maximum value.

Table 2. Detect EAR fluctuation calculated using the common method of the left eye.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|-------------|--------------------------|--------------------------|-----------------------|
| 50 – 70     | 0.30                     | 0.50                     | 0.20                  |
| 120 – 190   | 0.25                     | 0.44                     | 0.19                  |
| 240 – 270   | 0.15                     | 0.45                     | 0.30                  |
| 330 – 360   | 0.14                     | 0.43                     | 0.29                  |
| 420 – 540   | 0.16                     | 0.39                     | 0.23                  |
| 650 – 700   | 0.24                     | 0.42                     | 0.18                  |

Table 3. Detect EAR fluctuation calculated using the suggested method of the left eye.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|-------------|--------------------------|--------------------------|-----------------------|
| 50 – 70     | 0.28                     | 0.35                     | 0.07                  |
| 120 – 190   | 0.31                     | 0.37                     | 0.06                  |
| 240 – 270   | 0.17                     | 0.35                     | 0.18                  |
| 330 – 360   | 0.28                     | 0.34                     | 0.06                  |
Figures (9) and (10) show the actual values of EAR for the right eye over time that has been obtained using the proposed and the common approaches respectively. Tables (4) and (5) show the actual values of EAR fluctuation detection for the right eye over time. Some of the notes that can be made from the results: the minimum value for the EAR fluctuation detection is (0.13) and the maximum is (0.33) for the common approach, while for the proposed approach, the minimum value of the EAR fluctuation detection is (0.03) and (0.27) for the maximum value.

Table 4. Detect EAR fluctuation calculated using the common method of the right eye.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|-------------|--------------------------|--------------------------|-----------------------|
| 50 – 70     | 0.13                     | 0.30                     | 0.17                  |
| 120 – 190   | 0.25                     | 0.50                     | 0.25                  |
| 240 – 270   | 0.15                     | 0.38                     | 0.23                  |
| 330 – 360   | 0.26                     | 0.39                     | 0.13                  |
| 420 - 540   | 0.16                     | 0.49                     | 0.33                  |
| 650 - 700   | 0.35                     | 0.50                     | 0.15                  |

Table 5. Detect EAR fluctuation calculated using the suggested method of the right eye.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|-------------|--------------------------|--------------------------|-----------------------|
| 50 – 70     | 0.18                     | 0.30                     | 0.12                  |
| 120 – 190   | 0.32                     | 0.43                     | 0.11                  |
| 240 – 270   | 0.17                     | 0.33                     | 0.16                  |
| 330 – 360   | 0.31                     | 0.34                     | 0.03                  |
| 420 - 540   | 0.31                     | 0.44                     | 0.13                  |
Figures (11) and (12) show the actual values of the average EAR over time that has been obtained using the proposed and the common approaches respectively. As shown in tables (6) and (7) below, the minimum value for the average EAR fluctuation detection is 0.12 for the common method and equal to 0.04 for the proposed method, while the maximum value of the average EAR fluctuation detection is 0.17 for the common method and for the suggested method is 0.07.

![Figure 11: average EAR values that are calculated over time using the common method](image1)

![Figure 12: average EAR values that are calculated over time using the suggested method](image2)

**Table 6.** Detect EAR fluctuation calculated using the common method.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|------------|--------------------------|--------------------------|-----------------------|
| 50 – 70    | 0.24                     | 0.38                     | 0.14                  |
| 120 – 190  | 0.26                     | 0.43                     | 0.17                  |
| 330 – 360  | 0.26                     | 0.38                     | 0.12                  |
| 420 – 500  | 0.31                     | 0.43                     | 0.12                  |
| 640 – 660  | 0.27                     | 0.44                     | 0.17                  |
| 730 – 750  | 0.20                     | 0.34                     | 0.14                  |

**Table 7.** Detect EAR fluctuation calculated using the suggested method.

| Time (msec) | The minimum value of EAR | The maximum value of EAR | Fluctuation detection |
|------------|--------------------------|--------------------------|-----------------------|
| 50 – 70    | 0.27                     | 0.32                     | 0.05                  |
| 120 – 190  | 0.31                     | 0.39                     | 0.08                  |
| 330 – 360  | 0.31                     | 0.35                     | 0.04                  |
So we concluded that the improvement of the fluctuation detection was about 50% with the suggested approach.

7.2 Appearance with glasses, sunglasses, night glasses and without glasses.
The system works properly if the driver does not wear glasses and the use of glasses, sunglasses and night glasses by the driver does not impede system performance as long as the eye area is not completely removed as shown in Figures (13), (14), (15) and (16) respectively.

7.3 Detection with noise
Different random noise values from the Gaussian distribution were added to a video. Tables (8) and (9) below show the six (x, y) coordinates for the right eye of the driver with different noise values, the points at their correct positions when the noise level = 0 dB but these points move away from their original positions by increasing the noise value (noise level = 40 dB and noise level = 50 dB).

Table 8. The coordinates (x, y) of the right eye with the effect of noise level= 40db on these points.

| Noise level=0 (x, y) | Noise level= 40db (x, y) | Amount of shifting |
|---------------------|------------------------|--------------------|
| (110,85)            | (111,85)               | (1,0)              |
Table 9. The coordinates (x, y) of the right eye with the effect of noise level = 50 dB on these points.

| Noise level=0 (x, y) | Noise level= 50db (x, y) | Amount of shifting |
|----------------------|--------------------------|-------------------|
| (110,85)             | (111,86)                 | (1,1)             |
| (116,82)             | (116,82)                 | (0,0)             |
| (122,85)             | (122,83)                 | (0,2)             |
| (127,85)             | (127,88)                 | (0,3)             |
| (121,85)             | (121,88)                 | (0,3)             |
| (115,85)             | (115,87)                 | (0,2)             |

7.4 System robustness against noise

The percentage of probability of detecting landmarks in their correct locations from 100 tries has been calculated and the results were: 100% when the noise level = 0 dB, 94% when the noise level = 10 dB, 83% with noise level = 30 dB, etc., this percentage decreases with noise level increasing until the probability becomes zero when the noise level is more than 130 dB as shown in figure (17).

![Figure 17](image)

**Figure 17**: the percentage probability of landmarks detection in their correct points with different noise levels effect

8. Conclusions. In this paper, real-time driver awareness detection has been introduced. EAR has been calculated using a new proposed method. This method shows a maximum detection fluctuation of 0.18 which gives about 45% enhancement for EAR detection. Driver awareness can be detected even when there is a high level of noise reach to 130 dB. Sunglasses
transparency is also tested and the system was very robust. The algorithm has been applied to a number of persons (males and females), the same results were obtained.

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