Contributions to driver fatigue detection based on eye-tracking

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Received: September 28, 2020. Revised: January 10, 2021. Accepted: January 15, 2021. Published: January 18, 2021.

***Abstract*— In recent years, one of the most important factors in road accidents is the drowsiness of drivers and the distraction while driving. In this paper, we describe a system that monitors the detection of fatigue or drowsiness.**

The proposed solutions follow the driver's gaze, and if the system identifies the closed eyes, it triggers an alarm signal intended to alert against losing control of the car and causing traffic accidents.

Eye-tracking is the process that measuring the eye position and eye movement.

The proposed method is structured in three phases. In the first phase, eye images are captured at constant time intervals and converted into grayscale images. In the second phase these images are fed to Haar algorithm to identify the driver eyes.

In the third phase, based on the previous phase the system can now take action to continue monitoring or trigger alarm to alert the driver if the drowsiness has been detected.

Keywords—Eye-tracking, driver gaze, driver attention, driver fatigue.

Introduction

Personal vehicle transport has become the most popular transport activity among all other transportation systems. Consequently, driving has become an essential activity in personal mobility and autonomy worldwide. This activity includes neuropsychology capacities mediated by multiple areas of the brain, involving attentional, perceptual, visual, psychomotor, and cognitive abilities.

Drowsiness detection systems were developed using mathematical algorithms for eye and face detection. In this paper, we analysed the existing systems and apply Haar algorithm to detect the driver eyes.

According to [1], while driving, the attention from the steering wheel is distracted by various elements such as information on route in the navigation application or the indicators on the roadside. Advanced Driving Assistance Systems (ADAS) aims to increase the decision-making autonomy of the vehicles - the autonomy that will help drivers against the stress associated with the long-distance driving, and to provide traffic safety, by correcting human errors.

But ADAS can not detect whether the driver is having any drowsiness or fatigue.

I. Facts and statistics

According to [2], the National Highway Traffic Safety Administration conservatively estimates that in over 100,000 police-reported crashes each year, the “driver fatigue” was the main cause leading to 1,550 deaths and more than 70,000 injuries, resulting of $12.5 billion in monetary loss.

Fatigue causes a reduced ability to concentrate while driving and is manifested by a very slow reaction time, decreased alertness, reduced information processing and short-term memory accuracy [3].

Factors that generate fatigue are diet, medical conditions, lack of sleep.

According to [3], while driving when feeling tired, many people try to compensate for the influence of fatigue by increasing their speed to increase adrenaline or lower their speed to increase their safety margin. However, compensatory ways to eliminate fatigue have not been shown to be effective.

Numerous studies show that continuous driving for a long time is equivalent to 0.05 blood alcohol levels, which doubles the risk of an accident [10].

Table 1 Proportion of crashes related to sleep or fatigue

Crash category	**%**	**Number of studies**
All	1-6%	7
All fatal	3-15%	3
Truck driver crashes	2-41%	5
Truck drivers fatal crashes	4-31%	5

Source: Sagberg et al, 2004

Police reported crashes in different countries in Europe indicate values between 1-4% incidence of sleep related crashes [3].

Having a system that could detect drowsiness and driver fatigue could prevent such loss and save lives.

A. Defining driver distraction

Distraction can be defined as a lack of attention while driving. It affects drivers regardless of age or experience. It is the leading cause of road accidents worldwide.
According to specialists, there are three main groups of distractions behind the wheel:
Visual distraction: occurs when distracted by mobile phone, radio volume adjustment, and public panels;
Cognitive/mental distraction: generated by drugs/alcohol consumption, thus affecting driver's concentration.
Physical distraction: occurs when other activities are performed while driving, i.e. sending messages while driving.

Most of the time, various kinds of distractions occur simultaneously, with dire consequences.

B. Eye Traking System

Continuous monitoring of driver's behaviour and reactions is the basis of a reliable car safety system. Eye tracking, as a main component of safety feature, is a technology that can measure and analyse the movements of an eye, by following where a person is looking, what a person is looking at and for how long a person's gaze is in a particular spot [6].

Accurate detection of EOR (Eyes Off the Road) involves the combination of three essential components:
1) Facial feature
2) Head position and gaze estimation
3) 3-D Geometry

Recognizing the driver's movement and warning him if drowsiness is detected while driving is an essential technology needed for safe driving. When the system detects the driver's distraction, the alarm will be trigger: "Warning, please pay attention, wake up".

A user-oriented communication technology can also be developed, and eye tracking technology will make great contribution to the development process.

Eye tracking technology has continuously been developed and today it be applied to wide range of areas.

II. THE DEFINITION OF THE HAAR ALGORITHM

Haar algorithm was proposed by Alfred Haar in 1909. It is an algorithm for detecting the object in an image or video and is based on the concept of identifying the features proposed by Paul Viola and Michael Jones [4].
The principle is established on a new representation of images called "Full image".
The second contribution is based on the creation of a new learning algorithm based on the AdaBoost method which aims to select some visual features to produce classifiers that have proven to be fast and efficient in identifying images.
The third method combines the previous methods in a "cascade", which can be associated with a focusing mechanism on the areas of interest specific to the object.
The Haar algorithm runs at 15 frames per second and identifies the area of interest without the need to detect skin colour or the difference between the images.
According to studies and research in the field, the detection of images and faces in videos by applying the Haar waterfall classifier is one of the most efficient detectors that can be used in real time [4].

A. Algorithm

The main steps for detecting the state of the drivers could be divided into the four main blocks as shown in the flow chart in Figure 1.

• In the first part, the aim is to detect the driver's state. We considered that it is very important to verify if the device that is used for detecting eyes (in this case video camera) is functional or not.

• In the second part, check if the images are clear and correctly collected. If confirmed, the eyes are localized and the system computes eye state.

• In the third part, the system decide whether the driver's eyes are closed or open.

•In the fourth part decision is made to continue monitoring or triggering the alarm.

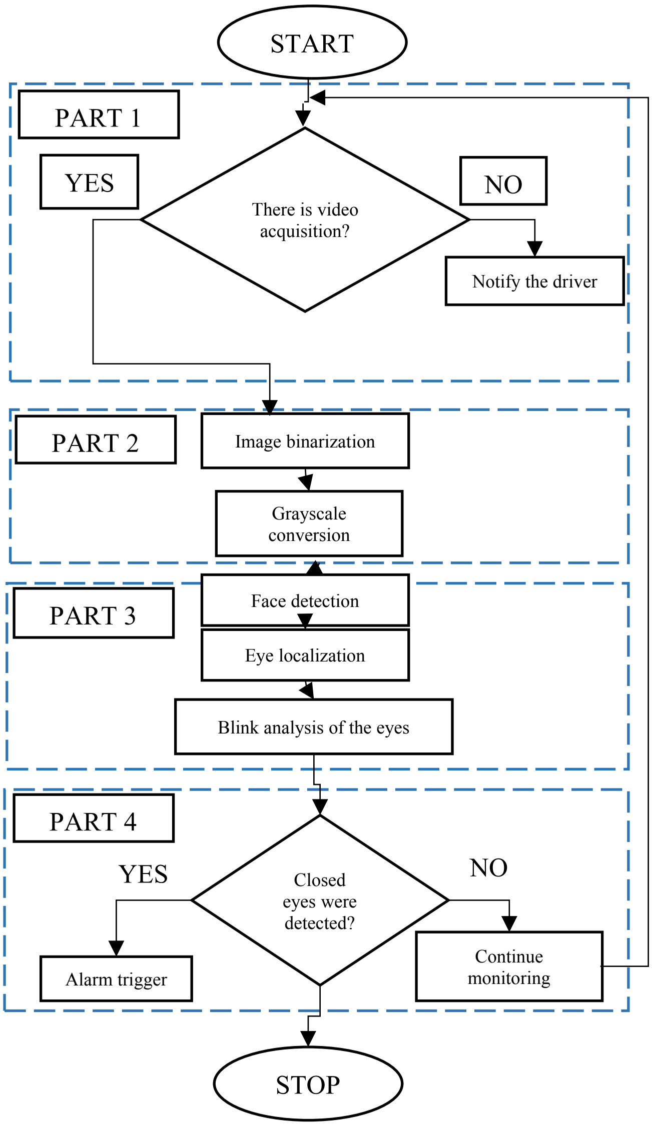

Figure 1 Eyes tracking algorithm for detecting fatigue and gazing

B. *Methodology*

- Part 1: Video Acquisition

  A webcam mounted on board the vehicle will take over the images.

- Part 2: Processing Image

  To applying the Haar algorithm, the color image captured by the video camera will be converted into a grayscale image.

In real images there is now completely white or completely black pixels because it is a gray scale image [5].

Figure 2 Gray scale image for detection edge and line features

Depending on the horizontal or vertical Haar features, the driver's face will be identified.

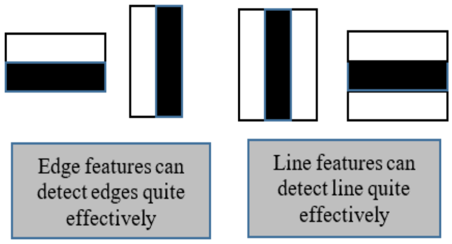

Figure 3 Haar features for face detection

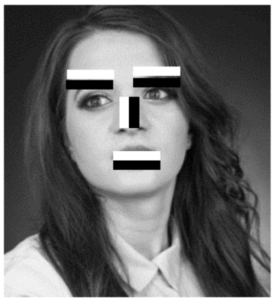

Figure 4 Detect human faces based on horizontal/vertical line features

Every single pixel has the value between 0 to 1 forming a grayscale.

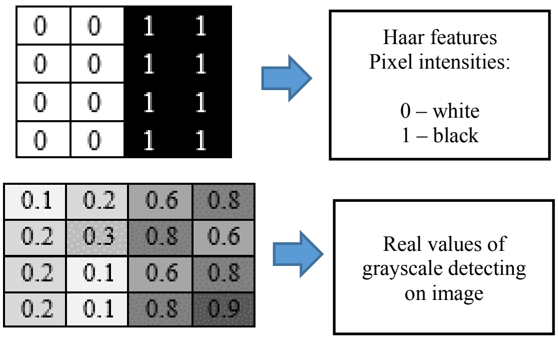

Figure 5 Haar features - pixel intensities and real values of grayscale detecting on image

As you can see the eyebrow contain the black pixels and the forehead above the eyebrow contains whiter pixels.

This is very similar with the edge features (which contains white pixels and dark pixels)

We can use line features that can detect lines quite effectively. For instance, the lips can be associate with horizontal line features.

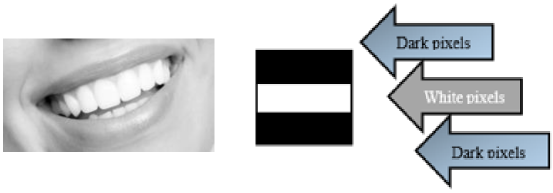

Figure 6 Association of the lips with the horizontal line features

In the same way we can detect the nose using vertical line features.

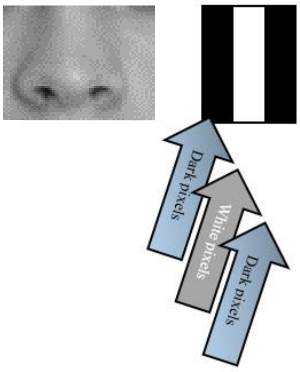

Figure 7 Association of the nose with the vertical line features

- Part 3: Face detection and eyes localization

  In this step we analyze the images provided by the previous step and supplying them to the Haar cascade classifiers, first classifier identifies the driver face and the second identify the driver eyes.

  After having the results from the classifiers, we analyze further the results and determine the eyes state and number of blinks.

- Part 4: Alarm trigger

  After applying the steps mentioned above, the system will make an analysis and decide on the driver's condition. If drowsiness is detected, the alarm will sound.

C. *Simulation results and discussion*

Each eye is divided into six coordinates in axis (x, y), numbering starting from the bottom left corner, and continuing clockwise [8].

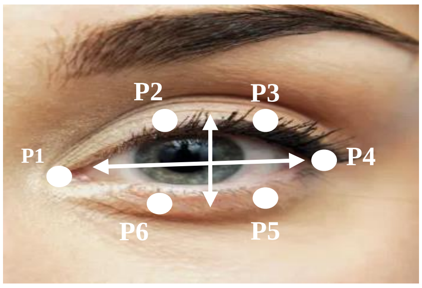

Figure 8 Six facial markers associated with the eye

Based on the image above, key points such as the Eye Aspect Ratio (EAR) can be calculated:

$$\mathrm{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|} \qquad (1)$$

For each frame identified in the video, the Eye Aspect Ratio is calculated. This technology is used to identify the number of flashes.
When the driver closes his eyes, the EAR drops to approximately level 0, and the opening of the eyes returns to normal [7].

When the EAR records a value lower than a defined threshold within 5 seconds, the state of drowsiness is identified and an alarm signal will be triggered.

As shown below on figure 9, on the left side the eye is completely open and therefore The Eye Aspect Ratio is almost constant over time. However, while the person is blinking, the Eye Aspect Ratio decreases greatly, approaching 0.
As illustrated in the signal representation, the Eye Aspect Ratio is constant, gradually decreasing as the person blinks and returning to the first state, indicating that only one blink has occurred.

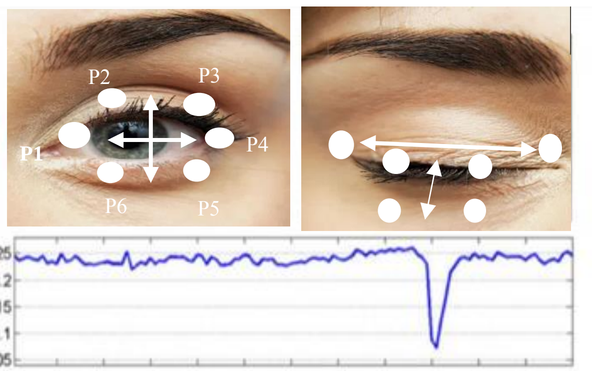

Figure 9 Viewing the landmarks of the eyes when they are closed and open

III. Experimental results and analysis

A. Face and eye detection

To detect drowsiness, we used Python as a programming language and apply Haar algorithm using dlib and OpenCV. An important step in detecting the driver's drowsiness is to identify the areas of interest of the face.

As we have shown above, the Haar algorithm helped to identify regions of interest that include eyes, nose, mouth, and eyebrows.

The dlib facial detector identified 68 coordinates specific to the face structure [9].

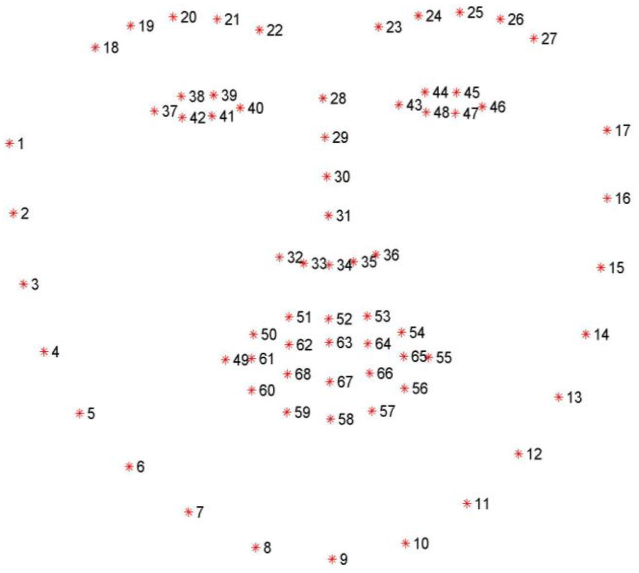

Figure 10 Face coordinates identified [Source https://pyimagesearch.com/]

The 68 coordinates are positioned on the x and y-axis [9].

Thus, the area of interest in the identified areas is:

Right eye: [36,42]
Left eye: [42,48]
Right eyebrow: [17,22]
Left eyebrow: [22,27]
Nose: [27.35]
Mouth: [48,68]

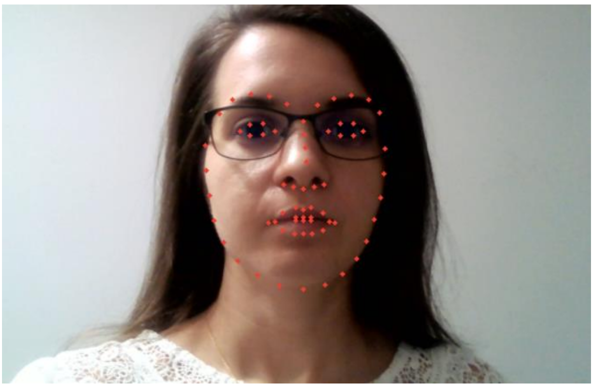

Figure 11 Detecting facial landmarks

To detect eye position (closed or open) we applied the Eye Aspect Ratio formula:

$$EAR = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

The EAR principle is represented by dividing the eye region into 6 coordinates, distributed on the x and y-axis clockwise [9].

The result of this formula calculates the Euclidean distance between the vertical and horizontal coordinates of the eyes.

Considering the EAR result as the basic method for identifying drivers' fatigue, we performed the following experiments.

We have defined two values. The first value represents the default value of 0.25. If the EAR decreases below this default value and subsequently increases, it means that a flash has been recorded.
The second value indicates that 60 successive frames have been recorded with a value less than 0.25 (default value).
After recording Eye_Aspect_Ration_trigger = 60, the system will generate the alarm signal.

a) Eye_Aspect_Ratio_threshold = 0.25
b) Eye_Aspect_Ration_trigger = 60

The application will consider an eye blink when the EAR value is less than the defined threshold and 0.

If a value equal to 60 records, it means that the system has identified the closed eyes and will generate an alarm signal.

The result of the experiment is presented below:

Table 2 Eye Aspect Ratio threshold

Eye_Aspect_Ratio_threshold	Eye_Aspect_Ration_trigger
0.25	60
0.3	50
0.41	40

B. Detect human face based on Haar algorithm features

When a car is driving on a road, locating or detecting the driver's eyes is not easy. First, the face will be detected, and then the surface will be narrowed to detect the eyes. By doing this, the tracking result and speed can be improved.

The Haar algorithm has good robustness in terms of head movements, variable lighting conditions, hair change, and wearing glasses.

C. APPLICATION FOR FACE AND EYE DETECTION

a) Face detection

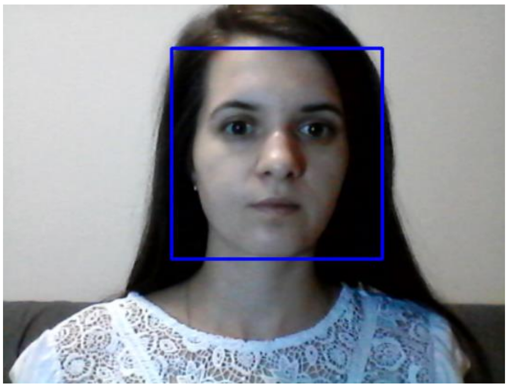

Figure 12 Face detection by applying the Haar algorithm

b) Looking detection

Figure 13 Looking center detection

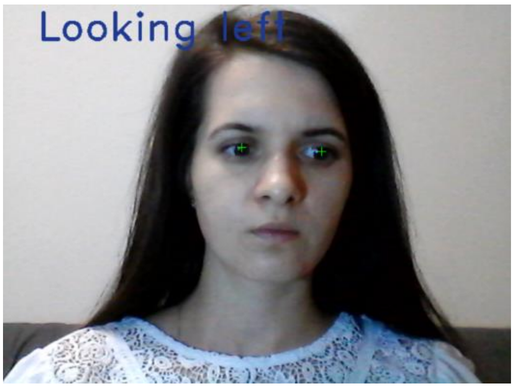

Figure 14 Looking left detection

c) Drowsiness detection

Figure 15 Drowsiness detection

CONCLUSION

In this paper, we have presented the ways of image processing and analysis using the Haar algorithm.
We have identified the threshold where the application offers the best identification results.
Through this system installed inside the cars, the number of road accidents caused by fatigue, drowsiness, or carelessness at the wheel could be greatly reduced.
To identify the drowsiness of drivers, it was first necessary to identify the regions of interest of the face: eyes, nose, mouth, and eyebrows. After identifying the areas of interest, we analyzed the eye area.
The application measures the Euclidean distance of the eyes both vertically and horizontally.
Following the EAR result (Eye Aspect Ratio) obtained, it is determined whether the eye is closed or open.
The contribution made in this study is the location and tracking of the driver's gaze, to identify if his attention is distracted while driving.
For higher accuracy, in the future, an infrared video camera could be used to help identify the eyes at night or in a low light environment if the driver is wearing sunglasses.

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