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Vigilance and Tiredness Detection by Analyzing Eyes Blinking

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Abstract— **Reduced vigilance driving is the third factor in accidents after alcohol and speed, then it can be considered as a dangerous problem where it seems important to detect and prevent this condition in order to improve road safety. The approach is the face detection method by "Viola & Jones", the extraction of facial components, and the analysis of vigilance by detecting the iris of the eye. We have studied the different existing approaches for face detection and we have decided to choose the method of "Viola & Jones". We have applied the algorithms on a database consisting of eight videos for different people (made in the laboratory). We have obtained satisfactory results (94.53% for the face detection, 89.38% for the edge detection, 99.45% for the eye detection and 100% for the forehead detection). According to the results obtained from the application of the algorithm to detect the iris, we note that blinks are correctly detected by a percentage of 89.69%. In this case, we have proceeded to view the curve blinking in real time to the vigilance state.**

Keywords- Reduced vigilance; iris detection; eye blink analysis; vigilance state

I. INTRODUCTION

The reduced vigilance is the transition between two states: wakefulness and sleep. It is responsible for one third of the fatal accidents on the highway. While fatigue corresponds to the exhaustion of the body following a hard activity, the reduced vigilance may be a consequence of fatigue.

There are various consequences of reduced vigilance: decreased vivacity, increased time of decision, increased feelings of fatigue, decreased motivation, etc. For all these consequences, driving in this state presents a great danger. For this, we must develop a system that measures and controls the vigilance status of the driver. This system allows preventing against accidents and improving road safety.

The recognition of the vigilance status of any person has three major problems to be solved. They are the face detection, the facial feature extraction (components), and the facial expression analysis (to detect reduction vigilance).

There are four theoretical approaches for face detection: ones respectively based on knowledge, invariant features, matching template, and appearance [1].

We have chosen for face detection the technique proposed by Paul Viola and Michael Jones [2]. This method combines four key concepts that are rectangular features or pseudo-Haar features, the integral image, the Adaboost algorithm, and the cascade of classifiers. The cascaded classifier algorithm minimizes the computational time. This technique allows a fast detection enabling it to be executed in real time and meet the demands of video processing.

There are two approaches for detecting the vigilance status: analysis of physiological signals (electroencephalogram (EEG), electro-occulographic (EOG)) [3] and analysis of visual signs. The analysis of physiological signals is difficult to achieve in real driving conditions. The analysis of visual signs is done by using a video camera; we can achieve it in real driving conditions.

Many works have been interested in the eye-based control of computer systems in the literature. In [5] the authors used spatio-temporal filtering and variance maps to locate the head and find the eye-feature points (Lucas–Kanade tracking algorithm). The method developed for processing blink waveforms was robust against the influence of differences among individuals [4]. In [6], the used method was the eye blink done by a signal analysis of multi-scale and multi-orientation Gabor responses of eye images. In [7], the area of the iris was measured using eye positional information obtained by the partial eye template matching method, and an eye blink was judged when the area of the iris became below a threshold. An implementation method based on the GPU implementation of the SIFT feature point extraction algorithm ensured real-time processing, presented in [8]. A case study of liveness detection using eye blink was presented in [9]. In [10], the authors used the eye-blink-based fatigue detection to prevent the computer vision syndrome. The use of the camera for the eye Blink was presented in [11].

We have a worked in this paper on detecting the reduction vigilance by a video analysis of the driver. This approach is to detect eye blinking starting with the detection of the iris. Indeed, the video approach can find non-intrusive eye parameters (blinking, eye direction, facial expressions etc).

II. APPROACH OF ANALYZING EYE BLINKING

The first step of the system is capturing a video (25images/s). The second step is the pretreatment (Gaussian filter, gray level transformation, and decomposition of video frames). The third step is face detection, by using the method of "viola & Jones" [2]. The fifth step is to extract facial features (forehead, eyes and mouth) and then we separate these characteristics for analysis. The sixth step is the extraction of the eye image; in this step we cut an image of one eye (not both eyes) to use it for the detection of the iris. The seventh step is the detection of the iris of the eye, to analyze the blink. Then one proceeds to the detection of the iris in all frames of the video. The eighth step is to extract eye blinking and its duration. The last step is the recognition of the vigilance state (sleep, wakefulness or tired). Indeed, it is known that during normal blinking, the eye remains closed for 0.2 s (in our case 5 frames) and during slow eye blinking remains closed for 0.5 s (in our case 12 frames). Hence, we conclude that if the duration of eye closure exceeds 12 frames, the person is in sleep onset or tired and it is not a normal blink.

A. Method for detecting vigilance by video analysis

This method of detecting vigilance is based on two steps. The first step is the detection of the iris of the eye. The second step is the detection and measurement of the eye blink.

1) Detecting the iris: The eye image is converted to grayscale and the image is filtered by a Gaussian filter. Indeed, this filter reduces the noise in the image for a better edge detection. Then we use a canny filter for the edge detection [12]. The use of an edge detector is essential to the detection of the iris of the eye. It has a good circle detection for the Hough transform method. We proceed for the application of the Hough transform to detect circles in the edge image of the eye. The detected circle corresponds to the iris in the eye. If the circle is detected in the eye image then the eye is open, else the eye is closed.

2) Detection and measurement of the eye blink: By scanning the video stream, we can determine the status of the closing and opening of the eye in every frame. We analyze these statements, then we determine the time of closing and opening of the eye, and the frequency of blinking.

B. Analyzing eyes blinking method implementation

We have applied this method on a database made in our laboratory. These videos are captured by a camera with a 5.3 mega-pixel resolution and a 25frames/s frequency, and a 720×576 size with a strong light. The videos are taken for 4 people (8 videos) (for each person there are two videos: one with normal blinking and the other with blinking tiredly).

1) Face detection: The detection methodology is to decide whether or not a face in the image exists. Indeed, the video is cut into frames, and then the video frame is processed. The detection allows following the movement of the detected face and getting a perfect result.

After detecting the face and determining its coordinates, we cut the face from the image. This detection method applies only to images in grayscale. Figure 1 shows the results obtained from the application of a face detection algorithm on our database.

Figure 1. Face detection of the data base

2) Facial features extraction: To minimize false detections, a method of estimating the position of the mouth and the eyes from the detected face is used.

The idea is to estimate the region of interest for each facial feature (eyes, mouth, and forehead) and use the appropriate Haar classifier to detect the eyes and mouth (Figure 2).

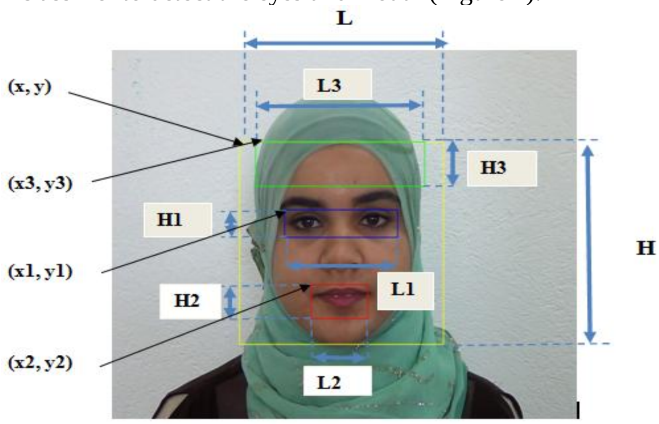


Figure 2. Cutting facial features

with: L: width face, H: length face, (x, y): face coordinates, L1: width of eyes, H1: height of eyes, (x1, y1): coordinates of first eye, L2: width of mouth, h2: Height of mouth and, (x2, y2): coordinates of starting point of mouth

Table I shows the results obtained during the application of face detection algorithm on a video from our database.

TABLE I. LOCATION OF FACIAL FEATURES

Facial Characteristic	Position x	Position y	Width	Height
Face	196	143	316	316
Forehead	211	143	262	69
Eyes	70	49	43	175
Mouth	111	13	53	88

With these coordinates, we can extract different face areas as shown in Figure 3.

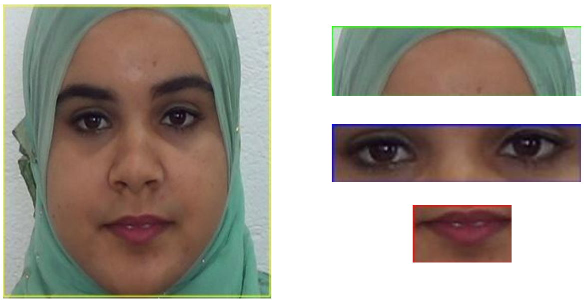


Figure 3. Different face areas: eyes, forhead and mouth

3) Detection and analysis of the iris: The images of eye opening and closing are represented in the following figure.

(a) (b)

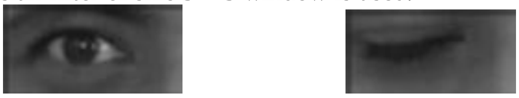
Figure 4. Result of cutting the eye : (a) Case of an open eye, (b): Case of a closed eye

Figure 5 represents the results obtained after converting the image to grayscale.

(a) (b)

Figure 5. Result of grayscale conversion: (a) Case of an open eye, (b): Case of a closed eye

Figure 6 represents the results of applying a Gaussian filter: a Gaussian filter of size 3 × 3 window is used.



(a) (b)

Figure 6. Result of applying the Gaussian filter: (a) Case of an open eye, (b): Case of a closed eye

4) Application of Canny filter: A Canny filter is used with a minimum threshold = 100 and a maximum threshold = 200 and a window of size 3 × 3 (Figure 7).

(a) (b)

Figure 7. Result of applying the canny filter (a): if an open eye, (b): if a closed eye

5) Application of the Hough transforms to detect iris circles: The Hough transform is implemented with the following parameters: the inverse ratio = 4, the minimum distance between the centers of the detected circles is equal to height × 2, The maximum threshold transmitted by the canny detector is equal to 60, the threshold of the accumulator for the centers of the detected circles is equal to 20, the minimum radius of the circle is equal to 6, and the maximum radius is equal to 18. The results of this method on an open eye and a closed one are represented in Figure 8.

(a) (b)

Figure 8. Result of the application of the Hough transforms: (a) Case of an open eye, (b): Case of a closed eye.

III. RESULTS AND INTERPRETATION

A. Results of detection algorithm and extracting facial components

The success rates of the detection algorithm and extracting facial components on our database are shown in Table II.

TABLE II. SUCCESS RATE OF DETECTION ALGORITHM AND EXTRACTING FACIAL COMPONENTS

video	face (%)	mouth (%)	eyes (%)	forehead (%)
video 1	92.72	98.55	100	100
video 2	99.03	100	100	100
video 3	96.81	90.64	100	100
video 4	87.2	96.69	99.56	100
video 5	99.52	61.96	100	100
video 6	96.32	94.37	99.62	100
video 7	93.21	84.51	97.46	100
video 8	91.45	88.73	98.96	100

Based on these values, the averaged success rates are:
The average success rate of face detection is 94.53%.
The average success rate of the mouth is 89.38%.
The average success rate of the eyes is 99.45%.
The average success rate of the front is 100%.

B. Results of blink detection

Figure 11 presents the results of the blink detection algorithm applied to our database. These curves are taken for tired and non tired people with normal blinking (Figure 9). Blinks are correctly identified with a percentage of 89.69%.

1) Normal blinking:

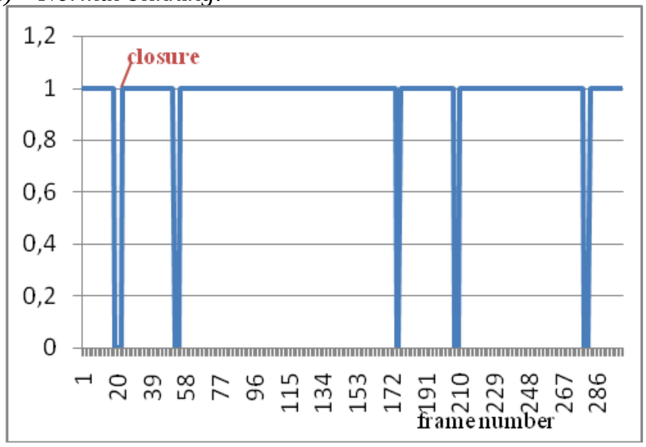


Figure 9. Visualization of the curve normal blinking

Times of opening and closing the eye are as follows:

TABLE III. DURATION OF OPENING AND CLOSING THE EYE

Opening	Time in seconds	Closing	Time in seconds
1	0.72s	1	0.16s
2	1.12s	2	0.12s
3	4.76s	3	0.08s
4	1.2s	4	0.12s
5	2.76s	5	0.12s

During normal blinking, the eye remains closed for 0.2s. During slow blinking, the eye remains closed for 0.5s. So, if the period of closure of the eye exceeds 0.5s then it is concluded that the person is in sleep onset or tired and the vigilance is reduced. In the case of Figure 9, we note that all durations of closures of the eye do not exceed 0.5 seconds, thus being a normal blink, so the person is awake.

2) Blinking with fatigue

TABLE IV. DURATION OF OPENING AND CLOSING THE EYE

Opening	Time in seconds	Closing	Time in seconds
1	**1.24s**	**1**	**1.56s**
2	**0.76s**	**2**	**0.28s**
3	**0.12s**	**3**	**1.56s**
4	**0.8s**	**4**	**0.12s**
5	**1.24s**	**5**	**1.56s**
6	**1s**	**6**	**2.56s**

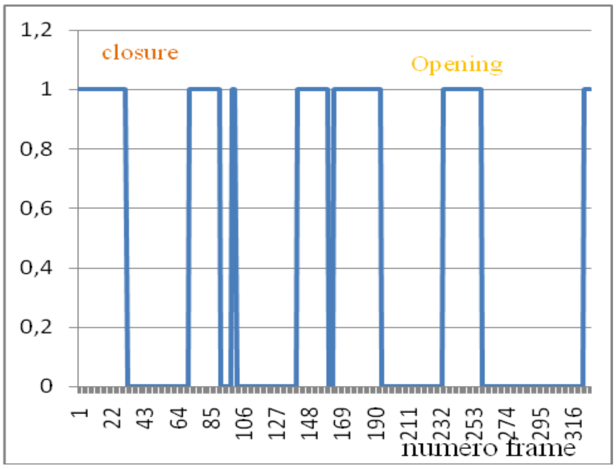


Figure 10. Visualization of the curve blinks for blinking with fatigue

Durations of opening and closing the eye are represented in table IV.

In the case of Figure 10, we see that the duration of the eye closures exceeds 0.5 s (1.56 s and 2.56 s), so the person is in sleep onset or tired.

IV. CONCLUSION

In this work, we have given the results obtained from the application of algorithms on our database (8 videos for different people). We have obtained satisfactory results (94.53 % for the face detection, 89.38% for the edge detection, 99.45% for detecting the eyes and 100% for the forehead detection).
From the results obtained from the application of the algorithm for detecting the iris, we notice that blinking is correctly detected by a percentage of 89.69 %. Analyzing the blink curve determines the vigilance state.

In this paper, the detection of the vigilance status is studied by analyzing eyes. Also, the vigilance status can be studied by analyzing the mouth (detection bailment).

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