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A VISION-BASED SYSTEM FOR MONITORING DRIVER FATIGUE

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Abstract

This paper presents a vision-based system for monitoring driver fatigue. The system is divided into three stages: face detection, eye detection, and fatigue detection. Face detection based on the skin color segmentation is used to localize face image from a whole image. To overcome the illumination changes in the driver's cockpit, the skin color segmentation technique based on a normalized RGB chromaticity diagram is adopted. After face is localized, eye is detected by projection technique of the gradient image and by extracting white color of eye's sclera. Then a PERCLOS (percentage of eye closure over time) is calculated and used to detect a fatigue condition.

Keywords : *Driver fatigue, machine vision, face detection, eye detecton, fatigue detection.*

Introduction

Driver fatigue is one of the main causes of traffic accidents. Statistics show that 20% of the fatal traffic accidents is caused by the driver fatigue [1]. In trucking industry, 57% of fatal truck accidents are due to driver fatigue [2]. A system that could monitor driver fatigue and give a warning to the driver is needed to avoid or reduce such problem [3],[4]. Many methods have been developed to detect driver fatigue such as using EEG (Electroencephalographic) signal [5], or by detecting the driver's grip force due to fatigue or loosing alertnes [6]. The drawback of those methods is the inconvenience of installing sensors on driver's body.

To overcome such inconvenient, the methods based-on machine vision are proposed by [2],[7], [8],[9],[10],[11],[12]. The main advantages of those approaches are no need sensors installation on driver's body, and could be implemented in real time. It only uses a video camera system installed on the car's dashboard for capturing image of the driver, usually the face. However, the approach facing the common problem in the image processing field, i.e. the problem of illumnination changes.

Most of existing methods utilize eye feature to detect the fatigue state. Usually they detect the opening/closing of the eye, and calculating the time of eye's closing, or the frequency of eye's closing/opening. Other methods utilize mouth's features are proposed by [13],[14],[15].

In this research, we propose a vison-based system for monitoring driver fatigue using eye's feature. To cope with the illumination problem, a color segmentation method based on normalized RGB chromaticity diagram is employed to detect a face. Further, the white color of eye's sclera and the projection of gradient image are used as the clue to detect the opening of eye.

The paper is organized as follows. Overview of the existing driver fatigue monitoring system is described in the next section. Then our proposed method is presented, followed by the experimental results. Finally, conclusion is given in the last section.

Overview of Existing Methods

A typical driver fatigue detection system is illustrated in figure 1[11]. It detects eye to determine the driver fatigue. Since position and illumination condition around the driver is changing during driving, to improve the speed and accuracy of the eye detection, eye should be localized and detected in the first video frame. To detect eye, firstly face detection is performed, then the searching area of eye could be limited in the area near/inside face region.

The common method for detecting face is by applying skin color segmentation to extract skin or face skin from a whole image. To cope with the illumination changes, several techniques are adopted, such as using

HSI color model [9], [16], mixed skin color model based on YUV and YIQ space [11].

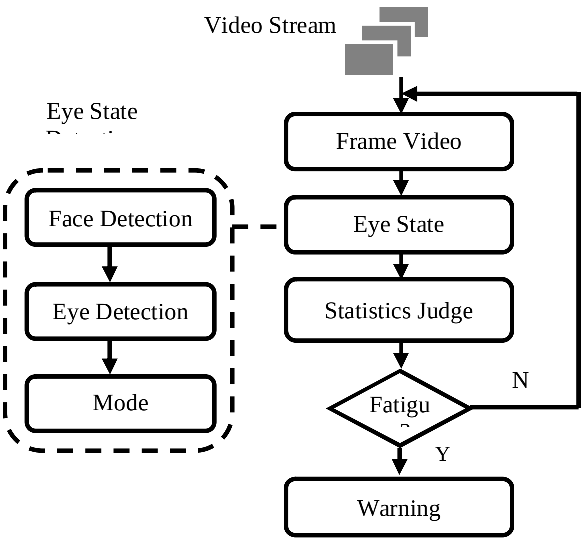


Figure 1. Flow diagram of driver fatigue detection system [11].

After face is detected, eye is searched in the region inside face. There are several techniques for detecting eye, such as template matching [9], Support Vector Machine (SVM) classifier [2], Hough Transform [12]. Other techniques using IR-illuminator are employed in [8],[10], which is based on the observation that by illuminating the eye with IR-LED, a dark and a bright pupil image could be obtained. Thus pupil or eye could be localized easily.

The general approach to detect driver fatigue is by measuring eyelid movement. Two parameters are used [2] : PERCLOS (Percentage of eye closure over time) and AECS (Average eye-closure speed). The degree of eye's opening is determined from the pupil's shape. If eye is closed, then pupil will be closed by eyelid and the shape becomes ellips. Thus the ratio of ellips's axes could be used to define the degree of eye's openess.

PERCLOS is calculated using the following formula [11]:

$$PERCLOS = \frac{Num\_CloseFrame}{Num\_SumFrame} x100\% \qquad (1)$$

where *Num_CloseFrame* is the number of frames when the eye is close, *Num_SumFrame* is the total number of frames observed. Based on P80 criteria, then a state is defined as fatigue if PERCLOS is greater than 20%.

Proposed Driver Fatigue Monitoring

In this research, we use the general framework for detecting driver fatigue, which is composed of three stages : face detection, eye detection, and fatigue detection. In the face detection stage, we employ our previous research on the skin color segmentation for face detection [17]. The approach is based on normalized RGB chromaticity diagram to extract skin color from image.

In the eye detection stage, we extend our previous method [17] to extract the white color of eye's sclera, and combining it with the projection of gradient image technique to find the position of eye.

Face Detection

To detect a face, first the skin color is extracted using the coarse and fine skin region, followed by an ellipse detection [17]. The coarse skin region is defined using fixed boundaries, where skin and skin-like colors (colors close to skin color) are extracted. To separate skin color from skin-like colors, the fine skin region with variable boundaries is employed.

The boundaries of the coarse skin region is defined by four lines as shown in figure 2. The *line-G, line-R, line-B,* and *line-up* are given as:

- *line-G* : $g = r$ (2)
- *line-R* : $g = r - 0.4$ (3)
- *line-B* : $g = -r + 0.6$ (4)
- *line-up* : $g = 0.4$ (5)

where

$$r = \frac{R}{R+G+B} \qquad (6)$$

$$g = \frac{G}{R+G+B} \qquad (7)$$

In addition to those four lines, a circle (*line-c* in figure 2) is used to exclude the white pixels, which is given as

$$\textit{line-c}: (g-0.33)^2 + (r-0.33)^2 = 0.0004 \qquad (8)$$

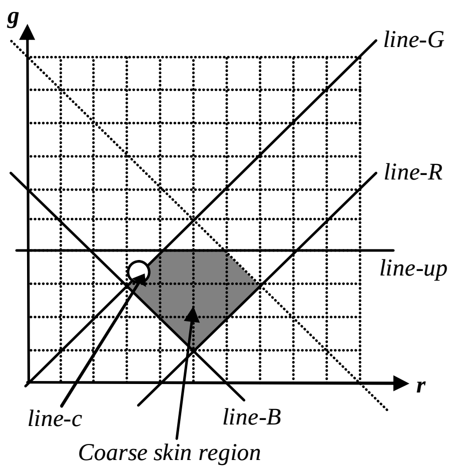


Figure 2. The coarse skin region [17].

The boundaries of the fine skin region are selected automatically by analyzing two developed histograms called *g_pos* and *g_neg*. *g_pos* histogram is created by counting pixels with the value obtained by subtracting *r* value from *g* value. *g_neg* histogram is created by counting pixels with the value obtained by adding *g* value and *r* value.

The left and right valleys of two highest peaks of *g_pos* histogram called as *PTL1*, *PTR1*, *PTL2*, *PTR2*, and those from *g_neg* histogram called as *NTL1*, *NTR1*, *NTL2*, *NTR2* are used as the parameter for defining the fine skin region using the following rules:

- Region-1:

IF ($PTL1 \le Pos \le PTR1$) AND ($NTL1 \le Neg \le NTR1$), (9)

- Region-2:

IF ($PTL1 \le Pos \le PTR1$) AND ($NTL2 \le Neg \le NTR2$), (10)

- Region-3:

IF ($PTL2 \le Pos \le PTR2$) AND ($NTL1 \le Neg \le NTR1$), (11)

- Region-4:

IF ($PTL2 \le Pos \le PTR2$) AND ($NTL2 \le Neg \le NTR2$), (12)

- Region-5:

Region-5 = (Region-1) $\cup$ (Region-2) (13)

- Region-6:

Region-6 = (Region-3) $\cup$ (Region-4) (14)

- Region-7:

Region-7 = (Region-1) $\cup$ (Region-3) (15)

- Region-8:

Region-8 = (Region-2) $\cup$ (Region-4) (16)

- Region-9:

IF $g \le 0.34$ (17)

- Region-10:

IF $(R + G + B)/3 \ge 0.33$ (18)

where

$Pos = g - r$ and $Neg = g + r$ (19)

Eye Detection

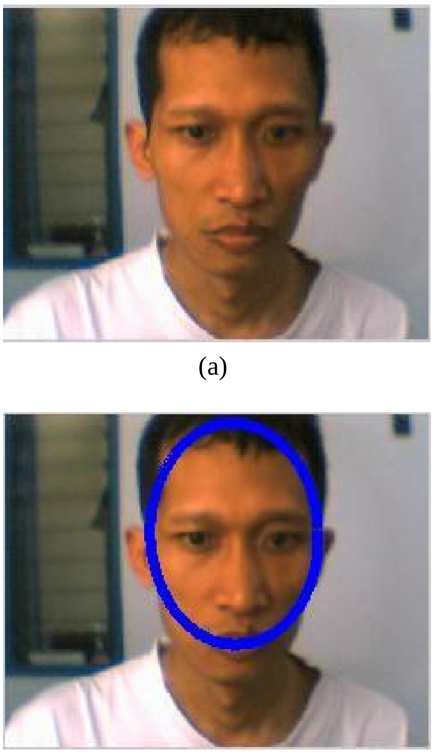
After face is detected, eye is searched in the area inside face. If we perform the horizontal projection of the gradient image inside face, then the peaks represent the vertical location of eyebrow, eye, and mouth. However the two highest peaks are the ones of eyebrow and eye. Thus we could utilize both two peaks to define the upper and lower position of eye.

To detect the opening of eye, a method similar to the coarse skin region is adopted. Hence the boundaries are limited to the white color, since the aim is to extract white sclera of eye. When eye is open then white color (sclera) is extracted, otherwise no white color is detected. Thus the number of white pixels could be used to decide whether the eye is close or open. The method works fine if there are no white objects near to the eye.

Experimental Results

We tested our method using MATLAB running on PC. A Webcam is used to collect the video data of a person during normal state (opening the eye) and fatigue state (closing the eye). Frame rate of the video is 30 frame per second. Apparently we conduct the off-line experiment, that is firstly video is recorded, then we extract each frame of the video as the input to the algorithm.

Figure 3 shows the result of face detection stage, where figure 3(a) is the original image, while the detected face is shown with ellipse drawn in figure 3(b). Gradient image of the detected face is shown in figure 4. From the figure, we might see that the dark colors dominate the eyebrow, eye, and mouth areas. Thus horizontal projection of the image will have peaks on those areas as shown in figure 5.



(a)

(b)

Figure 3. Result of face detection.

Figure 4. Gradient image.

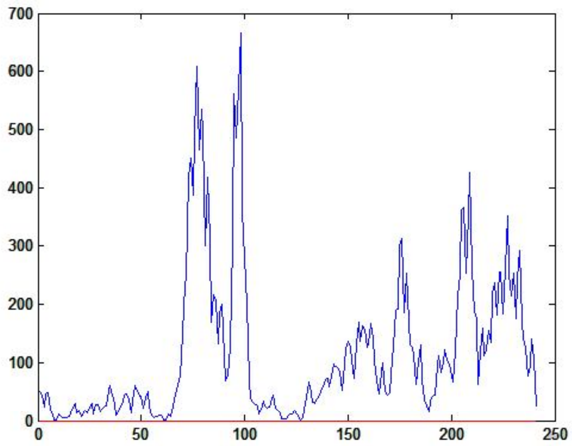


Figure 5. Horizontal projection of the gradient image.

Figure 6 shows the result of white color extraction using our proposed method as described in previous section. White color in the figure indicates the white objects extracted, i.e. eye's sclera.

Figure 6. Eye's sclera extracted.

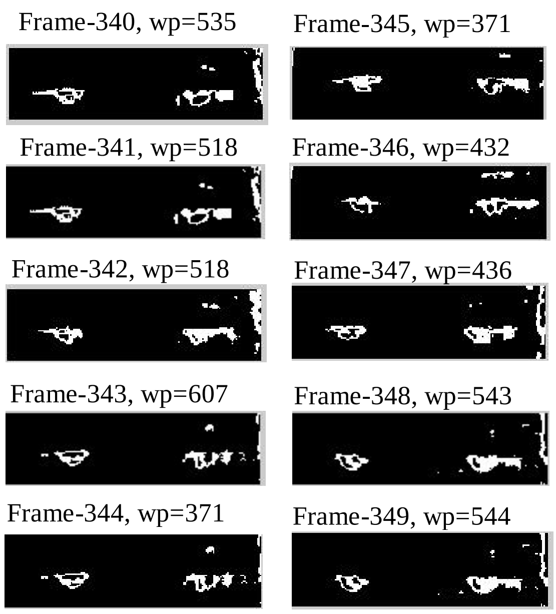


Figure 7. Eye's sclera extracted from frame-340 to frame-349 (*wp*=the number of white pixels).

Figure 7 dan figure 8 show the results of eye's sclera extraction of the video images, where from frame-340 to frame-349 (when eye is open) are shown in figure 7, while from frame-490 to frame-499 (when eye is close) are shown in figure 8. The number of white pixels denoted by *wp* is indicated in each figure. From the figures, we could see that the number of white pixels in figure 7 are larger compared to the ones in figure 8. Therefore we could detect the opening or closing of the eye by introducing a threshold to the number of white pixels.

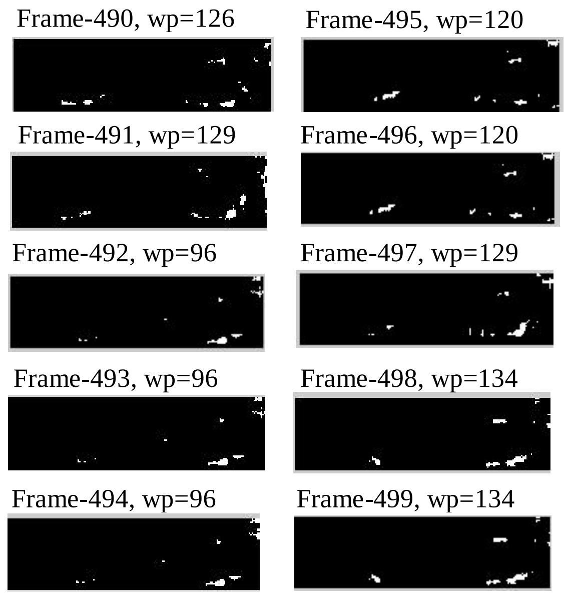


Figure 8. Eye's sclera extracted from frame-490 to frame-499 (*wp*=the number of white pixels).

Conclusion

In the paper, a vision system to detect driver fatigue is presented. The method employs a face detection technique to localize eye. The opening/closing of eye is detected by extracting white color of sclera in the eye's candidate area obtained by projection of the gradient image. Then, the fatigue state is determined by calculating the number of frames of the eye closing.

For future work, we will conduct the real experiments on the driver's cokcpit. Further the real implementation will be considered.

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