Machine Learning and Gradient Statistics Based Real-Time Driver Drowsiness Detection

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***Abstract* — In this paper, the machine learning and gradient statistics based driver drowsiness detection is developed for the real-time application. The proposed system includes four parts, which are the face detection, the eye-glasses bridge detection, the eye detection, and the eye closure detection. The system uses gray-scale images without any color information, and it works effectively in daytime and nighttime. For the face detection, the system uses the machine learning to detect face position and face size, and the face geometrical position is used to reduce the searching range of eyes. Next, the proposed eye detection algorithm for the eye location is separated into two different modes to judge whether the driver wears glasses or not. Finally, the system detects driver's eye state in the eye region. If the driver closes their eyes during an enough time, does not concentrate on driving, or nods his head, the system generates an alarm to notify the driver. In experimental results, the average processing frame rates are up to 245 fps in a PC (i7, 2.59GHz). The average detection rate of eye closure is 91.49% when the driver wears glasses, and the corresponding detection rate is 95% when the driver does not wear glasses.**

I. INTRODUCTION

For the past few years, many accidents caused by the fatigue driving have occurred frequently. Therefore, many researchers and experts all over the world have paid great efforts in this issue [1-3]. To detect driver drowsiness, some useful skills are ordinarily separated into three main divisions [1]: the first kind detects the driver's current state, which includes the closed eyes period, physiological state changes, and eye/eyelid motions. The second class refers the vehicle's behavior, e.g. the car speed. The third type refers both of the driver's state and the performance of driver [1]. For the fatigue/drowsiness detection issue, the driver's spirit status can be evaluated through the eye blinking condition. In this paper, by recognizing the accurate eye position, the effective eye detection methodology is proposed to enhance the accuracy of fatigue detections, and the machine learning and image gradients based schemes are utilized for the driver drowsiness detection design. The rest of this paper is discussed in the following.

II. PROPOSED DRIVER DROWSINESS DETECTION SYSTEM

The proposed system has four parts, including the face detection, the eye-glasses bridge detection, the eye detection, and the eye closure detection. Fig. 1 indicates the proposed operational flow, and the functions are described as follows:

2.1 Image Pre-processing

The input images are filmed by the NIR camera which has the 720x480 resolution. The system uses gray-scale images without any color information. To reduce the computational complexity, firstly the 720x480 image is down sampling to the 1/4 image scale. Next, the horizontal and vertical Sobel filtering is done. Finally, the integral image is computed to accelerate the following Haar-Adaboost based face detection.

2.2 Machine-Learning Based Face Detection

The Haar-Adaboost based face detection scheme [1] is applied to the proposed system design. In [5], the OpenCV functions (i.e. createsamples.exe and traincascade.exe) are used to train the face detector. For training, the positive samples are the face images with different angles, different brightness, wearing glasses, and not wearing glasses. After training, the obtained face classifier can detect the facial sizes, which are ranged from 240x240 to 320x320 pixels. The used face detector includes a 6-stage strong classifier, and the strong classifier at each stage is composed by 9 to 14-stage week classifiers.

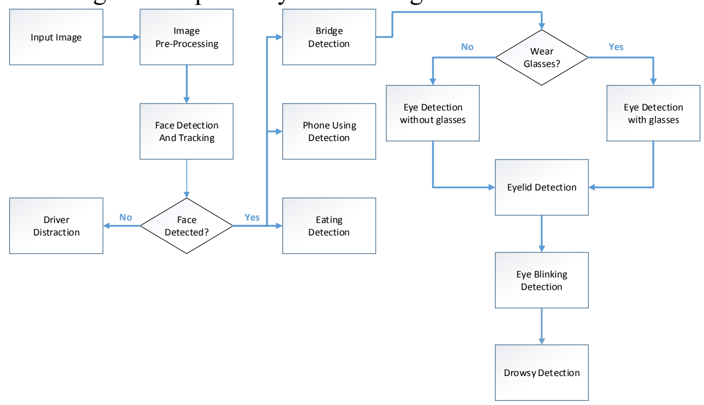


Fig. 1 The computational flow of the proposed driver drowsiness detection

2.3 Glasses Bridge and Eyes Detections

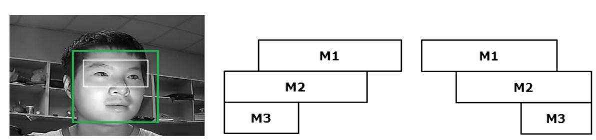
In Fig. 2(a), the green box region indicates the face detection result, and the blue box region is the candidate ROI of the glasses bridge, which is located by the geometric relation. When the edge information in the bridge region is larger than the threshold as shown in Fig. 2(b), the case with wearing glasses is detected. Fig. 2(c) shows the edge information in ROI when the driver does not wear the glasses.

(a) (b) (c)

Fig. 2 Glasses bridge detection

A. *Eye Detection without wearing glasses*

When the system does not detect the glasses, the eye detection scheme without wearing glasses is active. In Fig. 3(a), the white box area indicates the candidate ROI of the eye region, located by the geometric relation. Fig. 3(b) and Fig. 3(c) illustrate the applied eye filters to search the left and right eyes respectively, where the size of eye filter is scaled by the face size.



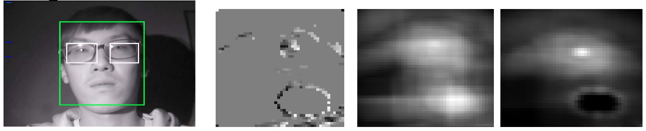
(a) (b) (c)

Fig. 3 Eye Detection without wearing glasses

B. *Eye Detection with wearing glasses*

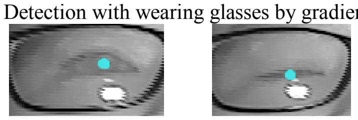
When the system detects the glasses, the eye detection scheme with wearing glasses will be enabled. Fig. 4(a) indicates the candidate ROI of the eye region. Firstly, the image gradients of ROI are calculated, and the X-axis and Y-axis gradients are used. In order to reduce the eye detection error, the interferences of the upper /lower eyelids and the reflection of light must be removed. By using the similar scheme in [4], the selected threshold is applied to eliminate the interferences. Fig. 4(b) shows the image gradients after the threshold processing.

By the gradient statistics based process in [4], Fig. 4(c) demonstrates the estimation results of eye center. After the proper weight process, the region of the reflection of light is masked, and the correct eye center location is estimated, where the region with the brightest gray-level is the location of eye center as shown in Fig. 4(d). Fig. 5 also demonstrates the results after the used eye center location processing under the obstacle of light reflection.



(a) (b) (c) (d)

Fig. 4 Eye Detection with wearing glasses by gradient statistics

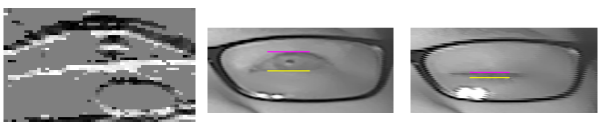


(a) (b)

Fig. 5 Eye center location : (a) Open eyes case (b) Closed eyes case

2.4 *Eyelid and Eye Blinking Detections*

By the horizontal gradient based eye image as shown in Fig. 6(a), the upper and lower eyelids are located to facilitate the open/closed eyes detection. Fig. 6(b) and Fig. 6(c) show the detection results of open/closed eyes conditions, respectively.



(a) (b) (c)

Fig. 6 (a) Horizontal gradient image (b) Open eyes status (c) Closed eyes status

III. Experimental Results and Comparisons

The proposed design is evaluated by a PC (i7, 2.59GHz) with the C/C++ language model, and tested by using several video sequences, which includes the drivers with and without wearing glasses in day and night, and the driver does not concentrate in driving, uses a mobile phone, and eats foods. The resolution of the tested video sequences is 720p, and the facial width of the driver in videos is ranged from 260 pixels to 320 pixels. Besides, the tested videos contain open/closed eyes conditions under the front face mode, the face mode by rotated within 30 degrees, and the situations of light and shadow variations. When the detect accuracy of open/closed eyes conditions is evaluated, the situations, which include a nodding behavior, the face is turned over more than 30 degrees, and the backward or forward action of head, are not be considered. When the head of the driver is turned over more than 30 degrees, the system recognizes that the driver does not concentrate in driving. Fig. 7 shows the serious reflective condition on the lens of glasses. In Fig. 7, the important eye region is blurred and damaged by the serious reflections, these video frames are not used in the performance evaluation. Figs. 8 and 9 (a)-(d) demonstrate the experimental results when the driver wears and does not wear glasses with normal, not concentrate, closed eyes, and drowsiness conditions, respectively. When the time period of closed eyes is larger than the threshold value, the drowsiness alert will be generated. In Table 1, by evaluated with the same tested video sequences, the average detection accuracy of open/closed eyes by the proposed design is 91.49%, which is better than that by the previous method in [3]. Besides, the processing speed of the proposed method is 225 fps, which is also faster than that of the design in [3].

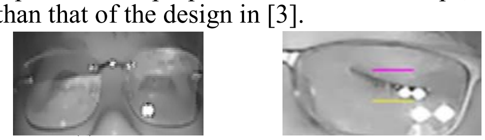
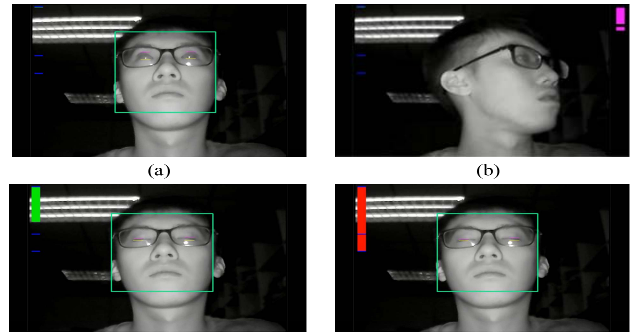


Fig. 7 The serious reflective conditions on glasses

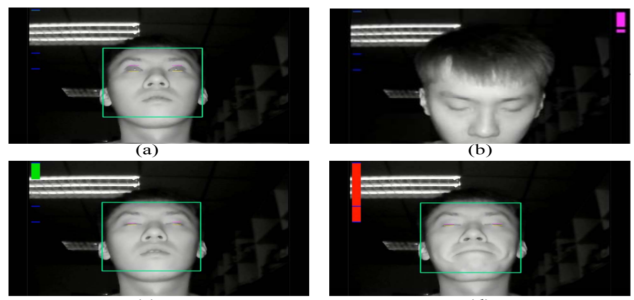
Table 1 Performance comparisons between two different designs

Applied algorithm	Li, etc. [3]	Proposed
Average detection accuracy of open/closed eyes	73%	91.49%
Processing speed	168 fps	225 fps



(a) (b) (c) (d)

Fig. 8 Experimental results when the driver wears glasses
(a)Normal (b) Not concentrate (c) Closed eyes (d) Drowsiness



(a) (b) (c) (d)

Fig. 9 Experimental results when the driver does not wear glasses
(a)Normal (b) Not concentrate (c) Closed eyes (d) Drowsiness

IV. Conclusion

By the machine learning and gradient statistics based technologies, the driver drowsiness detection is proposed for the real-time application. The proposed design uses gray-scale images without any color information, and it works effectively in daytime and nighttime. In experimental results, the average processing frame rates are up to 245 fps by a PC with 2.59GHz operational frequency. The average detection rate of eye closure is 91.49% when the driver wears glasses, and the corresponding detection rate is 95% when the driver does not wear glasses.

Acknowledgment

This work was supported by Ministry of Science and Technology, Taiwan, R.O.C. under Grant MOST 105-2221-E-005-078.

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