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Drowsiness Detection Based on Eyelid Movement

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***Abstract*—Fatigue driving easily causes traffic accidents. drowsiness is an important hint of Fatigue. A novel drowsiness detection algorithms based on eyelid movement is proposed in the paper. The cascaded classifiers algorithm is used to detect driver's face and the diamond searching algorithm used to trace the face. A simple fearure is then extracted from temporal difference image and used to analyze rules of eyelid movement in drowsiness. Furthermore, three criterions are also presented and used to judge whether a driver is drowsy or not. Experimental results show that this new algorithm achieves a satisified performance for drowsiness detection.**

Key Words: eyelid movement; drowsiness detection; three-level imae; region mark; judgement criterions

I. INTRODUCTION

Fatigue driving is an improtant reason that causes some fatal traffic accidents. Drivers in fatigue state easily lose their attention. Drowsiness is an important hint of fatigue. When a driver is drowsy, he frequently blinks, or closes eyes for a longer time. At the same time, his reaction speed to emergent occurrences is too slow to avoid traffic accidents in many cases.

Some research works have been performed in order to automatically detect driver's fatigue state. These works for driver's fatigue detection can be approximately divided into two categories: one use some physiological characteristics, and another use some facial image features [1]. The former detects the change of driver's physiological characteristics such as brain waves, heart rate and pulse rate [2-3]. Inspite the detection accuracy is good, but some special devices must be attached on driver's body. It is intrusive and not practical. The later detects eyelid movement, head movement, and yawning based on some image features [4-9]. It is nonintrusive and easily implemented. Therefore, it is a better and charming choice in practical applications. As known, eye state provides significant information. If such visual behavior can be measured, it is feasible to predict a driver's state of drowsiness, vigilance or attentiveness. Tabrizi presented a method to estimate the open or close state of eye by the number of pixels in pupil [5]. Mai proposed to use the open or close degree of eyelid and blinks time for drowsiness detection [6]. Zhang adopted a vertical projection technique to locate the position of eyes and judged open or close state of eye based on gray image feature [7]. Zhu used Kalman filter to track the eyes and obtain the parameters of the blink duration which are used to judge the fatigue of the driver [8]. Mohamad presented the distance between top eyelid and bottom eyelid for drowsiness detection by using a horizontal gray projection of top half facial image [9]. However, all these algorithms used high definition and high quality images so that the edge of eyelid or the size of pupil region can be easily detected. In fact, low definition and low quality images are usually captured by a simple camera because of vehicle vibration and illumination variation. It is difficult to exactly compute the edge of eyelid or the size of pupil region in practice.

A novel drowsiness detection algorithms based on eyelid movement is proposed in the paper. The cascaded classifiers algorithm and the diamond search algorithm are adopted to detect and trace face respectively. A simple fearure is extracted from a temporal difference image and used to analyze rules of eyelid movement in drowsiness. Then, three criterions are proposed to judge whether a driver is drowsy or not. Experimental results show that this algoithm can achieve a satisified performance for drowsiness detection.

II. FACE DETECTION AND TRACING

Face region was firstly detected in our algorithm. Among many face detection algorithms, the cascaded classifiers proposed by Viola and Jones is a good and fast face detector [10]. A software of the face detection algorithm was also provided in OpenCV [11]. When the algorithm is used in an embedded system, the large computation burden and memory accesses make the detection speed very slow. We used some strategies to speed up the face detector in our ARM embedded system, and the only about 1% of the time unused any strategy is needed. Motion information is used to trace face. Using a simple mask matching algorithm and a fast mixed diamond searching procedure [12], the speed of tracing face is about twenty times faster than a basic full range searching procedure. An example is illustrated in Fig. 1. The details were discussed in our previous work [13].

Figure 1. An example of detecting and tracing face in the embedded system

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III. EYELID MOVEMENT DETECTION

A. Temporal Difference Image

Generally, there are four kinds of eye state in two adjacent frames, such as, complete open, complete close, any middle state from open to close and from close to open. Eyelid movement can lead to change of image features in temporal difference image.

Since the movement of face region between current frame and previous frame can be compensated by the face tracing algorithm, the difference image between eye regions, a direct indicator of eyelid movement, can be also obtained easily. In order to remove noises in image, top half face image in each frame is firstly filtered by a mean filter with the size 3x3. Then an absolute difference image is computed and further converted into a bi-level image by an experimental threshold as (1):

$$g(x,y)=\begin{cases}255 & \left|I_c(x,y)-I_p(x,y)\right|>th \\ 0 & otherwise\end{cases} \quad (1)$$

where $I_c(x,y)$ or $I_p(x,y)$ is gray of pixel in filterred top half face image in current frame or previous frame respectively, th is the experimental threshold. An example is illustrated in Fig. 2.

(a) Previous frame (b) Current frame (c) Bi-level image

Figure 2. Two adjacent frames and a bi-level difference image

Obviously, eyelid movement can be easily judged by the bi-level difference image. The number of white pixels can be used as a judgement criterion. But it can not be used to discriminate the change of eye from open to close, or inversely. That is, the information is not enough to judge whether eye is open or close in current frame.

B. Indicator of Eye State

Eye includes three parts such as eyelid, sclera and iris. We notice that gray of pixel generally is higher in eyelid region than iris region and lower than sclera region. For two adjacent frames, a signed difference operation is proposed as (2):

$$g(x,y)=\begin{cases}-127 & I_c(x,y)-I_p(x,y)>th \\ 127 & I_c(x,y)-I_p(x,y)<-th \\ 0 & otherwise\end{cases} \quad (2)$$

The number of pixels with positive change in three-level difference image between current frame and previous frame is wrote as *Pcnt*, and the number of pixels with negative change is wrote as *Ncnt*. A large *Pcnt* represents eyelid movement from open to close while a large *Ncnt* represents an inverse procedure. Furthermore, we define *Pcnt-Ncnt* as a new indicator of drowsiness.

An example is showed in Fig. 3. It is clear that each period in the third curve completely represents eyelid movement. If a positive peak is prior to a negative peak during an eyelid movement, it means that eye varies from open to close, and then from close to open. And the succedent flatness segment in the *Pcnt-Ncnt* curve means that eye is always open. Contrarily, if a positive peak is behind a negative peak during a eyelid movement, it means that eye varies from close to open, and then from open to close. And the succedent flatness segment in the *Pcnt-Ncnt* curve means that eye is always close. It is important that frequency of blinks and the duration time of eye close state can be computed by the number of related frames. Such factors can be used as judgement criterions of drowsiness.

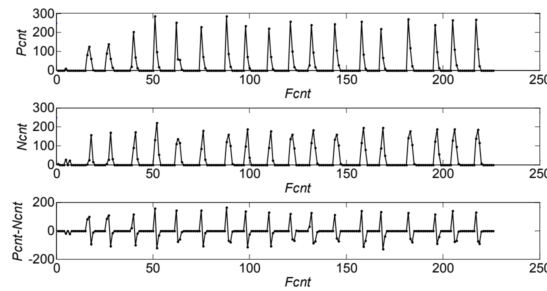

Figure 3. The numbers of changed pixels in eye regions

C. Extraction of Valid Changed Regions

In fact, a driver's head randomly moved and matching error always existed in the face tracing algorithm. Face expression, such as frown, can also produce some additional changed regions. Moreover, enviromental illumination also affects the qulity of image. Such factors produce more complex change regions than one in Fig. 1(c). Two such examples are provided in Fig. 4.

Figure 4. Extraction of valid changed regions

Only valid changed regions should be extracted for the judgement of drowsiness. A region mark algorithm is fistly adopted, and then three parameters, the central position (C_x, C_y) and the ratio (r) between width and height of each region, are computed. Valid changed regions can be selected by (3):

$$R_v(C_x,C_y,r)=\{(C_x>0.1*width \text{ or } C_x<0.9*width) \\ and\ C_y<0.6*height \text{ and } r>1\} \quad (3)$$

Finally, the number of changed pixels within selected valid regions in each red rectangle is wrote, as descriped in part B of section III. Because some blinks are related to the movement of eyebrows, the more regions are included sometimes.

IV. THE JUDGMENT OF DRIVERS' DROWSINESS

Normally, the eye blinks 10 times per minute, the interval is about two to six seconds, the duration of each blink is about 0.15 to 0.25 seconds, and the number of groups of continuous blinks is not more than two times. Therefore, three criterions are proposed to judge drowsiness.

The first criterion is the duration of eyelid closure. It is used as a distinctive characteristic to judge whether a driver is drowsy or not. It is computed by the number of frames between the positive prak and negative peak in the *Pcnt-Ncnt* curve. If the number of related frames is larger than a threshold, drowsiness is reported.

The second criterions is the number of groups of continuous blinks. It is another characteristic to judge whether a driver is drowsy or not. The number of groups of continuous blinks can be also computed by the positive praks and negative peaks from the *Pcnt-Ncnt* curve. Generally speaking, when a driver lies in normal spirit condition, the number of groups of continuous blinks is not more than two times; otherwise, he may be drowsy.

The third criterions is the frequency of eye blink. It is also used to judge whether a driver is drowsy or not. When a driver is drowsy, the frequency of his eye blink becomes slower. Contrarily, when he just becomes drowsy from normal spirit state, the frequency of his eye blink is faster during the conversion stage. The frequency is compted by the number of the positive praks or negative peaks within each time segment. If it is larger than 10 times per minute, drowsiness is warned.

V. Experimental results

We ask for ten students to test this algorithm in the experiments. The images captured by the simple camera are low resolution with the size 320x240 and some additional noises. Once face region in video is detected by the face detector, face region in next frame can be traced, as described in section II. When the error of the tracing algorithm is larger than a threshold, the face detector is used again. Then the *Pcnt-Ncnt* curve is computed, as represented in section III, and the three criterions in section IV are used to judge whether a driver is drowsiness or not.

These students are firstly asked to imitate normal blinks for a while. Three experimental results are shown in Fig. 5. Although the images with different face size, eye size, frequency and duration time of blink are captured, each *Pcnt-Ncnt* curve clearly shows the above four kinds of eye states during eyelid movement. Of course, the total number of changed pixels is different for each individual. But it is irrelevant to the three criterions for drowsiness judgement.

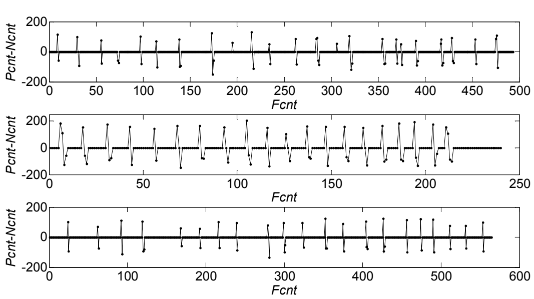

Figure 5. Three examples for normal blinks

These student are then asked to imitate blink in drowsiness for a while. Three experiment results are shown in Fig. 6. The first curve shows that the frequency of blink within each group is faster than normal frequency of blink. The second curve shows that the number of groups of blink is larger than a normal value. The three curve shows that a long duration time of eye closure happen after each positive peak. When the three criterions are used for drowsiness detection, the accurate rate reaches to above 98% in our experiments.

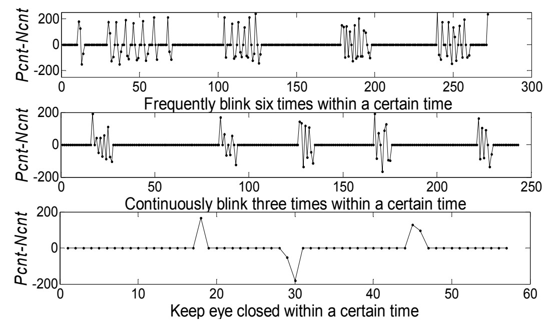

Figure 6. Three examples for drowsiness

VI. Conclusion

In this paper, a simple fearure is extracted from a temporal difference image, and three criterions are presented to judge whether a driver is drowsy or not. Shortage of standard databases at present, we can not compare our algorithm with others. Inspite under a simulation condition, the results are inspiring. The work is going to be studied completely.

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