Design and Simulated Implementation of MATLAB-based Warning System for Fatigue Driving Driver

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Abstract—**In order to prevent fatigue driving, through many studies of the driver's eyes, a Matlab-based fatigue driving detection system is designed and simulated based on image processing technology. The system samples sequences of images with an camera and its built-in light source, and then locates the eye-point in the image and tracks it, calculates the area of the eyes, finally makes judgment on whether the driver is driving with fatigue or not and warns him according to the judgment. The simulation test result shows that the recognition ratio of shallow fatigued drivers is 81.5%, and the recognition ratio of moderate fatigued drivers and deep fatigued drivers is 100%.**

Keywords-component; Detection System for Fatigue; Location and Tracking of Eye-point; Image Processing Technology;

I. INTRODUCTION

It is an important factor for causing accidents in traffic that the driver's fatigue [1]. Many countries are engaged in research in this area actively now, there has been the fatigue detector that can be divided into contact and non-contact types in the market, the principles are as follows:

(1)Fatigue can cause EEG changes. The EEG is not on the performance of the same when the cerebral cortex is in excitement or inhibition. According to the EEG's frequency distribution and waveforms, assumes the function status of the brain activity, so as to speculate whether the driver is fatigued. However the EEG is vulnerable to interference from external factors and there are so many differences in individual physiological response.

(2)Head posture. When the driver is fatigued, the head will always downward-sloping. According to statistics, the correlation coefficient of head position and fatigue degree is about 0.8. However, some driver's head posture will not change basically, the correlation coefficient will be negative ， and the system's judge and early warning failed.

(3)Steering wheel's rotation amplitude and handgrip strength. System detects the driver's mental state by monitoring steering wheel's movements and patterns. With the deepening of the driver fatigue, the number of greatly rotation will be increase; the handgrip strength will become larger.

(4)Road tracker. This method monitors the time and the deviation degree of vehicles leaving from the white lines by installing camera in the same perspective with the driver on the vehicle. This measurement requires the white line must be exist and clear enough on the road, so the interference of outside conditions is very great.

Therefore, how to effectively monitor and prevent driver fatigue driving has much real significance to reduce traffic accidents and personnel mortality[2]. After Comparison of the above fatigue alarm, the system through many studies of the driver's eyes, the research work in this paper include the four parts, i.e. driver’s face detection, driver’s eye locating and tracking, driver’s eye state recognition and driver’s fatigue state identification.

II. SYSTEM DESIGN

In order to enhance the accuracy rate of detection to the fatigue state of the pilot, this system extracts four state variables from the eye condition：It contains the frequency of blink, the average degree of opening eyes, the eye stagnation time and the longest time of closing eyes[3]. According to the parameter value of the pilot’s sober condition by statistics, it can make the corresponding judgment by the fatigue state of the pilot.

Considered the changing driving environment, the detection system must work normally in the night or the situation of inadequate lighting, therefore, this system adopts the camera with light source(automatic opening when the light is inadequate) to gather sequence image, in order to reduce the disturbance from the external environment. When the system reads in the frame image, it carries on the denoising and the image intensification process to the image first, and then obtains two real eye points. Afterward, it adopts the target tracking method to track the already targeted eye point[4]. At last, it can calculate the area of the eyes and make the judgment and the early warning to the fatigue state of the pilot. The functional block diagram of the system is shown in the following Figure 1.

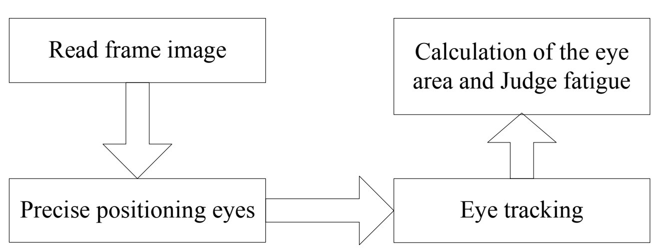

Fig 1 system principle diagram

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III. THE EYE'S LOCATES AND TRACKS

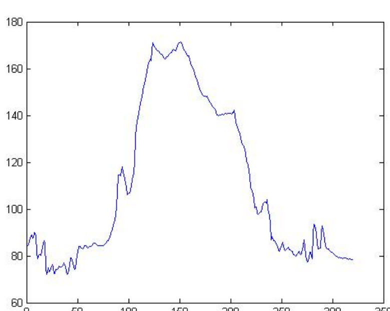
A. *Eyes Location*

In order to make the image smoothing, doing some treatments before eyes location, including image denoising and enhancement, which is a prerequisite to ensure precise eyes location achieve the better result [5].

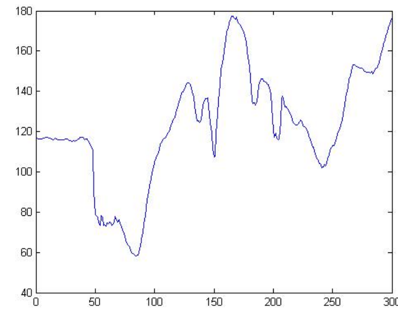
The first step: Locating the eye region roughly

The edge feature analysis method means, making use of the vertical gray-scale projection curve of the image determined the left and right borders of the face according to the convex peak width, then making use of the horizontal gray-scale projection curve of the gotten region determined roughly the up and down border of the eyes location region. The region that corresponds to a face is a convex peak with a certain width by observing the vertical gray-scale projection curve of a number of different single-face images. The left and right borders of the convex peak generally represented the left and right borders of the face [6]. When the left and right borders of the face are established, take the region of the face between the left and right borders as the study object, and then make the horizontal gray-scale projection curve of the image, something will be found by observing. The first minimum point of the horizontal gray-scale projection curve corresponds to the crown of the head, the maximum point corresponds to one of the forehead, the secondary maximum point corresponds to the central of the nose, and take the region between the central of the nose and the crown of the head as the rough located region (See Figure 2).

(a) the original image



(b) the result of projection from vertical direction



(c) the result of projection from horizontal direction

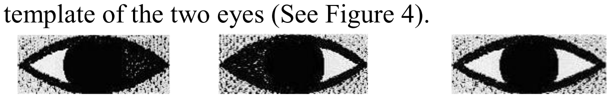
Figure 2 the results of projection from vertical and horizontal direction

After the edge feature analysis processing, the image is shown in the figure 3.

Figure 3 the image after the edge feature analysis processing

The second step: sifting the similar eye points collection

The primary problem is selecting the appropriate template prior to the template matching [7]. In the follow-up algorithm, it is necessary to use the relative position between two eyes to locate the two eyes from a number of similar points, so long as to ensure that there are two real eye-points among a number of similar eye-points. In order to reduce the two eyes' sensitivity to the eye template and improve the robustness, the system adopts the synthetic eye template of the two eyes (See Figure 4).



(a) left template (b) right template (c) synthesis template

Figure 4 the schematic of the eye template

In order to select the similar eye-points, it is desirable first to establish the similarity metric. The general way is doing the relevant operation to the local image and the image template, the cross-correlation coefficient obtained in this way is regarded as the similarity metric (See Formula 1).Two parameters are used to describe the synthetic template: template height M , width template N .

$$\rho_{xy}=\frac{\sum_{i,j=1}^{M,N}\left(T(i,j)-\overline{T}\right)\left(S_r(i+x,j+y)-\overline{S_r}\right)}{M\times N\times\sqrt{\frac{1}{M\times N}\sum_{i,j=1}^{M,N}\left(T(i,j)-\overline{T}\right)^2}\times\sqrt{\frac{1}{M\times N}\sum_{i,j=1}^{M,N}\left(S_r(i+x,j+y)-\overline{S_r}\right)^2}} \quad (1)$$

Therein, N is the synthetic eye template, the size is $M\times N$; $\overline{T}$ is the average of the eye template image; $\overline{S_r}T$ is the average of the local image that matches with the template in the expected face recognition image; (x,y) is the coordinates of search points in the face image.

According to the above formula, operating ρ_{xy}, always have $|\rho_{xy}| \le 1$, and the greater the ρ_{xy},the higher the matching. However, due to the synthetic eye template exists a certain error and image acquisition will be affected by external conditions, when the interference, these may lead to the greatest similarity is not the real eye point, so locating the eye point can not only be determined by the size of the similarity. In order not to miss the real eye point, the way is selecting roughly a similar eye point collection including the two real eye points (See Figure 5) $A=\{(X_i,Y_i)|i=1,2\cdots\cdots,n\}$, and then obtains the two real eye points through prior knowledge calibration. n is a optional coefficient.

Figure 5 the image of the screening similar eye-point collection

The third step: obtaining the real eye-point through calibration

The relative positions of two eyes to meet the relationship: the absolute value of the difference of the abscissa of the eyes' focal point is a within certain range; its longitudinal coordinates should be close to the same in the permitted range of the gesture change; the angle between the two eyes' line and the horizontal direction is from 45 °to 135 °. After the edge feature analysis and of the eye template matching, found the main interferential point in the similar eye-point collection is the eyebrows.

In order to locate the real eye-point accurately, it is first to add up a large number of face images whose actual size is equal to the human face, then get the statistics of the position relationship between two eyes; combining the any two similar eye-points, there are C_n^2 groups; then calculating the distance function values of each group by using the distance function (See Formula 2).

$$D(i,j)==\begin{cases} f\left(|X_i-X_j|,|Y_i-Y_j|\right) & c\times N<|X_i-X_j|<b\times N\text{且}|Y_i-Y_j|\le a\times M \\ A & \text{其它} \end{cases}$$
$$(i,j=1,2,\cdots,n;i\ne j) \quad (2)$$

Therein, $D(i,j)$ is defined as a distance between the two similar eye-points i,j, which can reflect the relative position between the two similar eye-points and the closeness of the relative position of the real two eyes [8]. The higher the closeness, the smaller $D(i,j)$, on the contrary the greater. The values of parameters a,b,c are gotten by counting according to the relative position of the partial face images in the library. You can get $a=\frac{\overline{Y}+(2\sim3)\times\sigma_y}{M}$, $b=\frac{\overline{X}+(2\sim3)\times\sigma_x}{N}$, $c=\frac{\overline{X}-(2\sim3)\times\sigma_x}{N}$; $\overline{X}$ and σ_x are respectively the mean and the standard deviation of the horizontal distance, $\overline{Y}$ and σ_r are respectively the mean and standard deviation of the vertical distance; A take a larger constant .

The group of the minimum distance (i,j) in the calculation results is the located result of the two eyes (See Figure 6), whose coordinates in the image are (X_i,Y_i), (X_j,Y_j) respectively.

Figure 6 the real eye-point image after correction

B. Eye Tracking

This system adopts the improved target tracking algorithm when it traces the eyes. The essence of target tracking is that it carries on the pinpoint while recognizing target in the image sequence [9].

The target tracking algorithm realized in this system divides into two parts: the primary algorithm and the modified algorithm. The primary algorithm is based on the template matching technology, namely, after pinpointing the eye point to the first frame image, it selects this eye point in the image as the tracking object and extracts appearance information of this eye point as the new eye template, in the following sequence image, it will match the candidate image region and this new eye template, then take the most similar image region as the position that this eye point in the current image.

The modified algorithm adopts the method of selecting candidate image region. It reduces the match times greatly, and then reduces the computation complexity of the system. The system uses the image gathering card for gathering image, and the rate is 25 frame per second, while the pilot driving, the head's amount of exercise is very small, therefore the position difference between the two neighboring frame images is very small, namely, it can obtain the roughly position of the eye point in the next image after pinpointing real eye point.

After adopts the target tracking algorithm, the system does not need to carry on an eye pinpointing for every frame image in the image sequence, but only repositions the eye point to the image which loses the tracking object, thus it improves operating efficiency of the system greatly and satisfies real-time request of the system too.

IV. CALCULATION OF THE EYE AREA AND JUDGE THE DEGREE OF FATIGUE

After the precisely location of the point in eyes, choosing the region of the eyes as the new model template, at the same time, doing the generalized symmetric transformation within the regions of the eyes in order to determine the position of the pupil center[10]. The system will extract the profile of the eyes from the eight upper and lower and sixteen left and right pixels region of the pupil center, calculate the areas of the eyes (S) through the region increasing and binary image (the number of pixel point included).Having gotten the areas of the eyes (S), the system could judge the fatigue degree of the driver based on the change of the areas of the eyes.

Nowadays, PERCLOS is usually regarded as evaluation index of the fatigue degree of the driver; it speculated the fatigue degree of the driver through the eye closure time rate (Rate) during some time, which is obtained from the statistical analysis for the time when the eyes areas is the minimum. The experiment shows that PERCLOS is approximate exact for the recognition of depth and moderate fatigue, but it is poor to shallow fatigue. So, this system is not only based on the large number experiments about the relations between the eyes statement and the fatigue degree, but also adopts two evaluation indexes, that the average degree of eye opening and the produced longest duration of eye closed. Among them, the average degree of eye opening is to calculate the average values of the degree of eye opening during some time, namely the average values between every time of blinking the minimum areas and the maximum areas ($S_{\max}$).The produced longest duration of eye closed is the longest time that the driver closes his eyes during some time, namely the time that the areas of eyes is the minimum during the time.

In the process of experiment, the state of the fatigue degree of the driver can be assorted into four degrees: conscious, fatigue in depth, fatigue in moderate and fatigue in shallow .As the table 1:

Table 1: Evaluation Standard for Fatigue State

Fatigue level	**State Characteristic**
Conscious	The normal change law of eyes' areas
Fatigue in shallow	Decrease of blinking frequency
Fatigue in moderate	The trend of eyes closed， increasing of time that the areas of eyes keep fixed value
Fatigue in depth	The severe trend of eyes closed，increasing of blinking frequency

V. CONCLUSIONS

The system requirements for the P4 3.06G CPU, 1024MB of memory or more to run the hardware environment, and simulates implementation using MATLAB 7.0 .The system is capable of accurate positioning eye point. Through the 465 laboratory tests on 31 persons, the results show that the recognition rate for shallow fatigue is 81.5 percent, and for moderate fatigue and depth fatigue are 100 percent. Using four parameters of eye states can effectively detect the driver's fatigue status. Of course, our system has some limitations. For example, if the driver wears sunglasses or his eyes are covered, this method will be ineffective. In order to improve the accuracy grade, our system should be using some other methods as a supplementary means, such as road tracking, head position, the rotation rate and the grip force of the steering wheel, which are the main directions to improve our system accuracy.

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