Accurate Human eye Positioning Based on the Geometrical Characteristics of eye and Brow

J.C. JIANG&C. ZHANG

(Engineering Research Center of Automotive Electronic and Embedded System, Chongqing University of Posts and Telecommunication, Chongqing 400065,China)

Keyword: Eye location; Eye and brow; Geometrical characteristics; Threshold segmentation; Experiments

Abstract. Human eye location plays a crucial part in machine vision fatigue detection. To address the difficulty of distinguishing eye and brow in traditional way of machine vision human eye location, this paper proposes an accurate human eye location way, which is based on geometrical characteristics of eye and brow, capable to avoid mistakes of eye and brow judgment, and makes locations fast and precisely. Firstly, with the most suitable threshold segmentation algorithm, separate the suspected human eye region from face through binary image; secondly, process the binary image of human face with mathematic morphology; lastly, make accurate human eye location by distinguishing eye and brow geometrical characteristics. As the experiments show, the method proposed in this paper can avoid the interference from brow and locate human eye accurately.

1 INSTRUCTION

Statistical reports at home and abroad show the accidents caused by driver's fatigue driving take up 14.9% of human injury accidents and 20.6% of fatal accidents. According to statistics, when traffic accident happens, if driver can react a half second earlier, 60% of those accidents can be avoided. Obviously, there is an urgent necessity to do fatigue detecting for drivers. For drivers, the no-contact machine vision fatigue detecting is the best preference, which judges driver's fatigue degree in the light of facial information. As to the method, eye positioning is the most important part, thus it makes human eye positioning in machine vision fatigue of great importance.

Generally, there are two considerations in the process of human eye detecting: one is real-time performance, the other is accuracy. The current human eye detecting methods are comparatively hardly to meet the two requirements at the same time. The method based on prior knowledge boasts good real-time, but it's hard to master the degree of rules while making conclusion of experiences, which makes it hardly to be popularized. The template matching method enjoys higher accuracy compared with the former one, but it's susceptible to posture, brow and external interference. The method based on statistics has high accuracy, but the demand of large quantity of samples makes it of complicated process and poor real-time performance. Gray projection method provides simple algorithm and good real-time, but it's susceptible to environment and with weak robustness.

After analyzing above methods and analyzing actual situation, this paper proposes a human eye-location method which combines threshold segmentation algorithm and eye and brow characteristics. Firstly, process the extracted facial images with linear graying; secondly, separate suspected human eye region from background with threshold segmentation; lastly, make accurate eye location according to eye and brow characteristics after morphological processing. The algorithm flow chart goes as Fig.1.

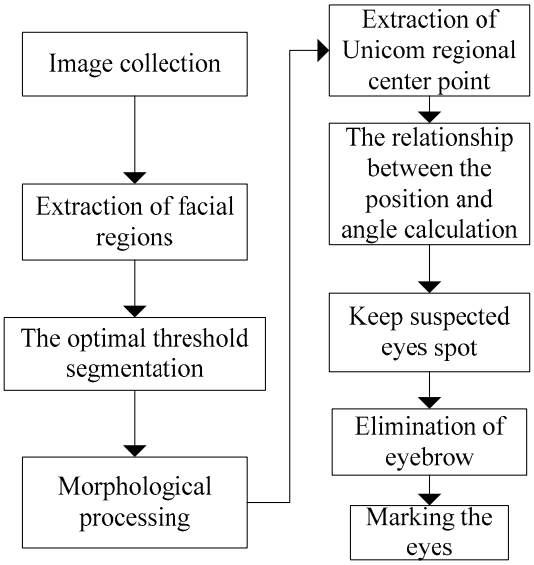

Fig.1 lgorithm flow chart

2 THRESHOLD SEGMENTATION EYE DETECTION METHOD

2.1 *Facial linear graying processing*

The gray of human eye changes larger than other parts of face, which makes it possible to adopt the most suitable threshold method to detect human eye in human face region. Process the marked facial region with linear graying to get human face grayscale image. The process goes as equation (1):

$$Gray = R = G = B = 0.299R + 0.587G + 0.114B \quad (1)$$

R, G, and B represent three channel component values in RGB space. Out of increasing the contrast ratio of facial image, facial region is suggested to go through linear processing. The process goes as equation (2)：

$$Gray = \begin{Bmatrix} k * Gray, if\,(k * Gray \le 255) \\ 255, if\,(k * Gray > 255) \end{Bmatrix} (2)$$

K equals 2.8. The contrast ratio of brow, eye, and some other facial parts increases greatly after the facial image being processed with linear graying.

2.2 *The most suitable threshold segmentation*

Pupil is the part of smallest facial gray, almost being black. But the gray of sclera, or to say eye white, is very large, almost being white. The main idea of this algorithm is to take advantage of eye gray changes, use iterative method to choose a most suitable threshold value, and then separate the-suspected human eye region from background, and finally achieve the goal to detect human eye. Firstly, preset an initial threshold T_0. In this paper, the initial threshold is set to be the average value of $Gray_{\max}$ and $Gray_{\min}$ of facial region.

$$T_0 = \frac{Gray_{\max} + Gray_{\min}}{2} \quad (3)$$

Take the image as two parts, detecting target and background. Then adopt iterative method to determine the average value of target threshold and background threshold, $Gray_O$ and $Gray_B$. The equations go as follows:

$$Gray_O = \frac{\sum_{f(i,j)<T_k} f(i,j) \bullet Num_{f(i,j)}}{\sum_{f(i,j)<T_K} Num_{f(i,j)}} \quad (4)$$

$$Gray_B = \frac{\sum_{f(i,j)>T_k} f(i,j) \bullet Num_{f(i,j)}}{\sum_{f(i,j)>T_K} Num_{f(i,j)}} \qquad (5)$$

$f(i,j)$ represents the gray of image on the point (i,j); $Num_{f(i,j)}$ represents the number of points with $f(i,j)$. At last, average the two thresholds to get a new threshold.

$$T_{K+1} = \frac{Gray_O + Gray_B}{2} \qquad (6)$$

The detailed process of this algorithm goes as Fig.2.

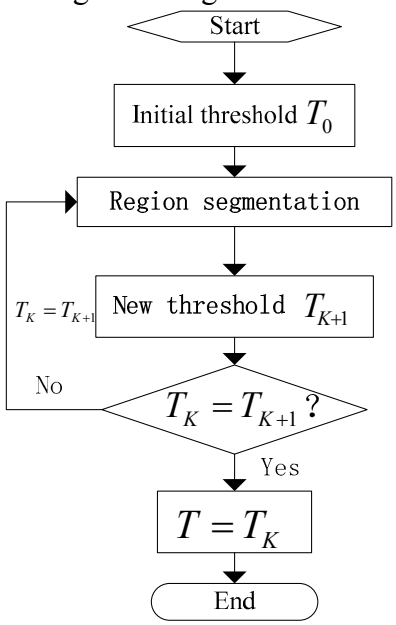

Fig.2 The most suitable threshold algorithm flow

If $T_K = T_{K+1}$, the algorithm terminates and the threshold $T = T_K = T_{K+1}$; otherwise, make $K = K + 1$ and continue the iterative method to determine $Gray_O$ and $Gray_B$ again. The effect picture after threshold segmentation goes as Fig. 3.

Fig.3 Binary image of face

3 MORPHOLOGICAL PROCESSING

Binary image is set to be processed in accordance with mathematical morphology, which, as a method to process nonlinear images, analyzes images with set operation and mainly targets on studying geometrical shape of images.

3.1 *Dilation operation*

Dilation operation, with the $\oplus$ operator, is applied in binary images to process lengthening or widening, which is used to fill the holes of objects. In equation (7), we say A is dilated by B.

$$A \oplus B = \{X \mid [(\hat{B})_X \cap A] \neq \Phi\} \qquad (7)$$

In that equation, B is the structural element; $\hat{B}$ is the mapping of B; and $(\hat{B})_X$ is the displacement vector x of B's image. When using B to dilate A, we should map the center pixel of B first, and then translate the mapping by x so as to avoid an empty intersection between A and B's mapping.

3.2 *Erosion operation*

Erosion operation is the dual operation of dilation operation. With the Θ operator, erosion is used to process shrinking or thinning. In equation (8), we say A is eroded by B.

$$A\Theta B = \{X \mid [(\hat{B})_X \cap A^C] \neq \Phi\} \qquad (8)$$

After discretization, many human eyes will appear in the binary image of eye region. Dilation processing can merge and restore the eye region while maintaining the aperture of eyes. Erosion operation then is used to restore the total width of eye region's binary image to that before dilation and restore the merged face region to its original shape so that eigenvalue can be maintained to ensure the final accrete location of eye region.

4 WIPE OUT THE PSEUDO HUMAN EYE REGION

4.1 *The proportion of the human eye position located on the face*

Out of simplifying operation and narrowing down detecting area, no-human-eye region is wiped out in accordance with the area ratio it takes up. In line with GB10000-88 standard, human eye is about in the middle of the head. In view of any raising head or lowering head, we relax the standard, setting it within the range of $\frac{5}{8}$ of face and wiping out the other $\frac{3}{8}$.

4.2 *The ratio human eye takes up of face*

There are several no-eye white areas after processing binary image with mathematic morphology, part of which may cause large area deviation. Those white areas will interfere with eye positioning, so according to priori knowledge, we wipe out such areas to improve its accuracy. Experiments are conducted to wipe out those no-eye areas taking up 1‰-1% of face. Fig. 4 is the effect picture.

Fig.4 Wiping out pseudo human faces

5 ACCURATE LOCATION OF EYE

As shown in Fig.4, most no-eye areas are wiped out only leaving eyebrow and nose. Due to the symmetry and close location of eyebrow, it's hard to separate it from eyes, so the relative location of eye and brow, as a supplementary condition, is taken into consideration to help accurately locating human eye finally.

In line with human biological indicators and GB10000-88 standard, the rules to distinct brow from eye are summarized as follows:

①Eyes are always between brow and nose. The distance between eye and brow is far short than that between eye and nose.

②Since drivers always look at the front horizontally when driving, the head-tilt won't over 45° and eyes, as a pair, won't tilt over 15°.

③Brow is above eye and the vertical intersection angle won't over 75°.

④The distance between two eyes takes up 35%-55% of the width of face.

With the help of the four characteristics mentioned above, this paper proposes a method to position human eye based on eye and brow locations and distinct eyes from other interferences. The process is shown in Fig. 5.

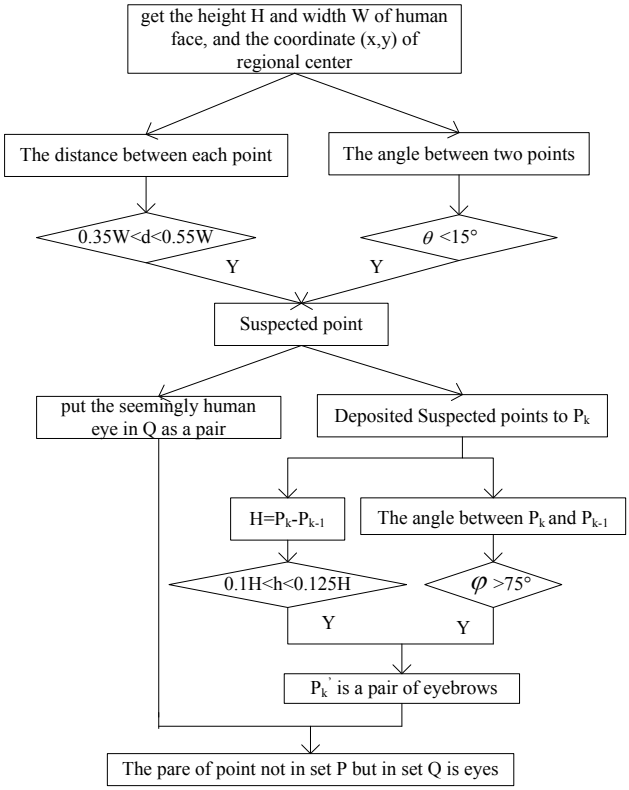

Fig.5 the process of human eye positioning

First, find out the width W and height H of human face with algorithm; then, work out the $I(x_i,y_i)$ coordinate of human eye region's central point in binary image that processed by optimal threshold segmentation. If there are two points meeting the following conditions at the same time, they can be taken as a pair of eyes of brows. The constraint conditions are as follows.

①The distance d between two points is: 0.35W<d<0.55W;

②The horizontal contained angle of the two points is below 15°.

After those operations, the interference from nares is eliminated. Targeted points are left in a pair, at least one of which represents eye or brow. Put the coordinate of each pair in Set M. Take out those points individually; find brow points in accordance with the following conditions.

①The vertical distance h between two points meets 0.125H>h>0.1H;

②The vertical angle of two points φ>75°.

If a point and a certain point in Set Q meet those two conditions, they should be brow points. This method is used to find out brow points. Compare brow with the two points in Set Q respectively, if there is a brow point, then this pair can be excluded. The left pair in Q should be human eyes. The final effect picture of human eye positioning is shown in Fig. 6.

Fig.6 human eye positioning

6 EXPERIMENTAL RESULT AND ANALYSIS

The simulation experiment is conducted on a personal computer. The experimental environment is Matlab7.9. This paper established a human face data including faces in different angles. The 100 images are pictured in normal light or downloaded from internet. Those images contain people in different postures or with different expressions and slightly tilted faces. Use the method of this paper to make human eye location, part of effect pictures are shown in Fig.7.

Fig.7 Part of effect pictures of human eye location

Use the method of this paper to check the accuracy of human eye location on 100 images. The experimental result shows as table 1.

Table 1. Experimental result

Sample size	Missing detection	False detection	Accuracyrate	rate	rate
100	5%	6%	89%		

7 CONCLUSIONS

Human eye positioning is an important step in fatigue detecting system. This thesis, taking the change of eye's grayscale into account, adopts optimal threshold segmentation and use binaryimage to distinct seemingly human eye region from face. Since the locations of brow and eye in human face are too close to be separated, a method is worked out to locate human eye based on the geometric characteristics of eye and brow. Results show this method is capable to eliminate the interference from brow and locate human eye accurately.

8 REFERENCES

[1] C. Gonzalez, E. Woods，Steven L. Digital Image Processing Using MATLAB [M].Beijing：Publishing House of electronics industry, 2009:252-260.

[2] King L M, Nguyen H T, Lai S K L. Early Driver Fatigue Detection from Electroencephalography Signals using Artificial Neural Networks[C].Proceedings of the 28th IEEE EMBS Annual International Conference,2006:2187-2190.

[3] LI Du-hou, LIU Qun, YUAN Wei,et al. Relationship between fatigue driving and traffic accident[J].Journal of Trafficand Transportation Engineering.2010,10(2):104-109.

[4] Tang Jie, Fang Zuhua, Hu Shifeng,et al.Driver Fatigue Detection Algorithm Based on Eye Features[C].The Seventh International Conference on Fuzzy Systems and Knowledge Discovery,2010:2308-2311.

[5] Tao Dan, Feng Xiaoyu. A fast algorithm for eye and mouth location matching based on integral projection and color[J].Application Research of Computers,2009,26(4):1578-1581.