An Effective Method and Device for Eye Detection with Physical Properties

Dongbing Quan
School of Electronic and Computer Engineering, Peking University
Shenzhen Graduate School
Shenzhen, China
quan1242@126.com

Yong Zhao, Jingjing Li
School of Electronic and Computer Engineering Peking University
Shenzhen Graduate School
Shenzhen, China
zhaoyong@pkusz.edu.cn

Hui Zheng
Changzhou Jiari Intelligent Technology Co., Ltd
Shenzhen, China
zhenghui001@hotmail.com

***Abstract*—Accurate detection of eyes plays an important role in human-machine interfaces. In this paper, according to some physical characteristics, a new designed device for the new real-time and effective eye detection method is proposed. In this device, two physical characteristics are applied, they are the Red-eye effect and the 850-property observed in the experiments. The detecting approach includes four steps, pretreating, matching by SURF (Speeded Up Robust Features), finding the difference and getting the points of the eyes. After these four steps, the positions of the eyes are obtained, and whether eye exists in the picture or not could also be judged. To speed up the detection, the matching parameters are recorded and adjusted periodically.**

Keywords-eye detection; SURF; red-eye effect;850-property

I. INTRODUCTION AND RELATED WORK

Eye detection is a key technology in a variety of human-computer interaction applications. For instance, it can be applied to a drowsy driving detection system to prevent accidents or to eyesight tracing of human-machine interfaces to make operation simpler. The eye detection is also very important for face detection, face recognition and facial expression analysis, which will be widely applied in the near future. The existing methods in eye detection can be classified into three types: the traditional image-based passive approaches [14-18], the mixed approaches [9-13], and the IR based active approaches [1-8].

The traditional approaches contain model based approaches, template based approaches and feature based approaches. Though they have some differences, they all detect eyes by exploiting the differences of the eyes in shape and appearance from the rest of the face. They all take face box as their input and assume that the face-detection is perfectly performed. However, the performance isn't optimistic in real applications.

The mixed methods use the near infrared camera taking pictures with the bright pupil first. Then, adopt the traditional image-based approaches to detect the eyes.

The active methods detect eyes by the images taken by the near infrared cameras. In this way, they utilize the red-eye effect to get the point of the pupils and then the eyes can be detected easily. The existing active methods can be classified into two types by the equipments they used.

One type is proposed by Antonio Haro, et al. [2-8], which utilizes only one CCD camera and get two images by two same IR led groups which are on and off camera axis respectively. They could get images with different brightness pupils as these two groups of lights are on and off alternatively. So, through subtracting the dark pupil image from the bright pupil image, the eyes' position could be obtained effectively.

The other type is firstly proposed by Richard Grace, et al which [1] used two CCD cameras to get two photos with bright pupil at the same time by filters and beam splitter. In their device, there are two groups of lights which all lie on camera axis. One group uses 850nm IR LED and the other 950nm IR LED. The basic physiological property of human eyes shows that the retina reflects only about 40% of the incident light at 950nm while about 90% at 850nm. So, they utilize this character to obtain two similar pictures only have differences in pupils.

In this paper, using physical properties, a new camera device is designed and a new real-time and effective eye detection method is proposed. The device is similar to Richard Grace's to some extent [1], but it has some other innovations as follows: First, less LED is applied to get more bright and clear photos, because the 850-property is taken into consideration firstly. Second, a ROI is defined and the SURF descriptor is used to aligning the pictures. These innovations make the result neater with less noise, compared with Richard Grace's device. Fig. 1 summarizes our eye detecting algorithm.

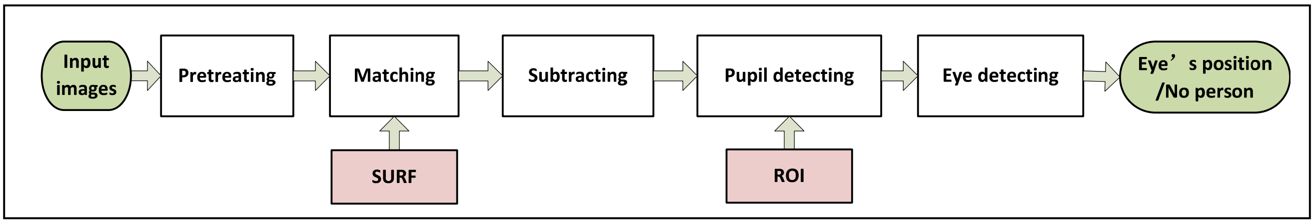

Figure 1. Overview of the eye-detecting

Published by Atlantis Press, Paris, France.

II. RED-EYE EFFECT

The structure of human's eye is similar to a set of optical system. It can be simply abstracted into an optical model. In this model, the lens in the eye can be regarded as a convex lens and the retina as an optical screen (Fig. 2). The light enters into the eye, and then images on the retina. According to the optical principles, some input light is absorbed and the other is reflected. If the light reflected from the retina can be received by the CCD, red-eye effect will happen.

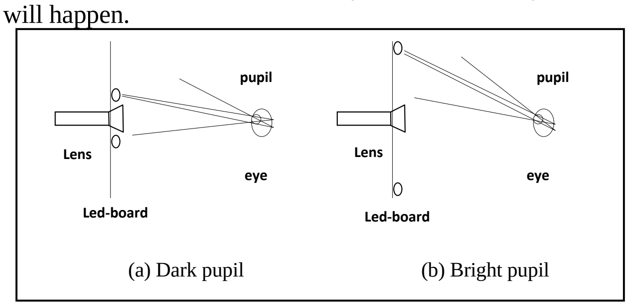

Figure 2. Principle of the red-eye effect

When the LED lay far beyond the camera axis are turned on, the light reflected from the retina can't be captured by CCD. So the pupil imaging on the camera is a dark one as Fig. 2 (a) shows. When the LED lay close to the camera axis to some extend, the reflected light can be captured by CCD and a bright pupil image will be obtained as Fig. 2 (b) shows.

III. THE 850-PROPERTY

During the experiments, a phenomenon is found: the distance between the LED-board and the lens of the camera is correlated positively with the exposure of the images for 850nm light. The structure of the camera and the LED-board is shown in Fig. 3.

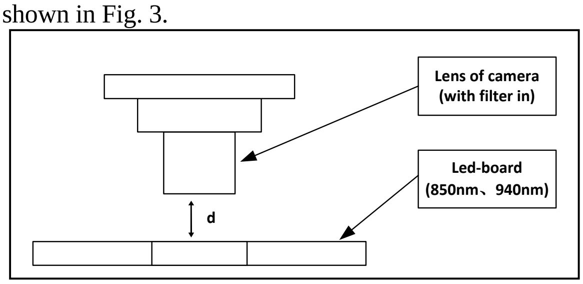

Figure 3. Equipment of the test experiment

Some pictures are taken with an increasing distance from the camera. Fig. 4 shows the pictures taken by the camera with 850nm filter. And Fig. 5 shows the pictures taken by the camera with 940nm filter. It can be found that the distance is correlated positively with the exposure of the images taken by the camera with 850nm filter, while the 950nm filter doesn't have similar phenomena. It is called 850-property in this study, and this phenomenon is applied to roughly adjust the background of the two groups of pictures in the device.

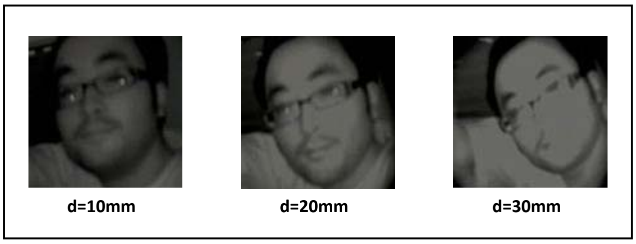

Figure 4. 850nm group

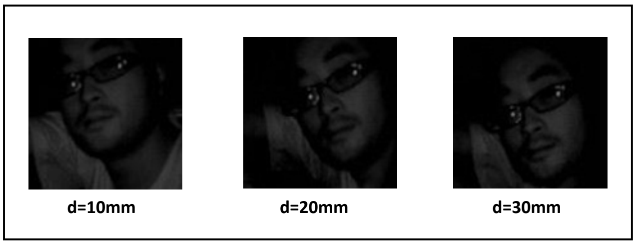

Figure 5. 940nm group

IV. THE CAMERA SYSTEM

The board on which LEDs are fixed is just as Fig. 6 shows. Two kinds of LEDs, 940nm LED and 850nm LED, are uniformly distributed on the LED-board. In the experiments, the LED-board is mounted in the front of the device.

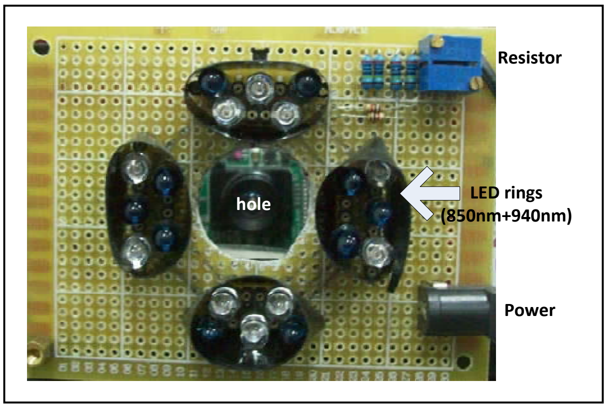

Figure 6. The led-board

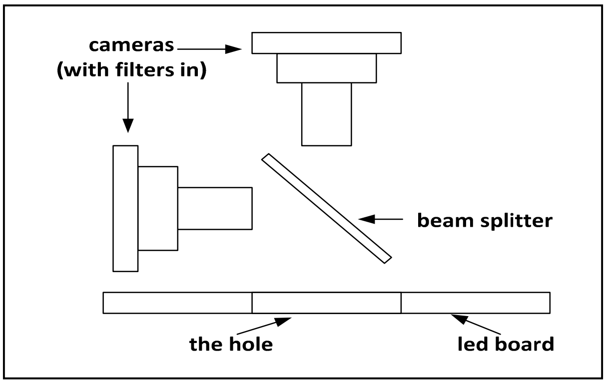

Figure 7. The camera equipment

As Fig. 7 shows, the camera device has the following components: 2 CCD cameras, 2 filters (940nm and 850 nm), 1 beam splitter (9:1), 1 LED-board.

V. APPROACH

The beam splitter, company with the 850-property as mentioned in Section III, is applied to roughly adjust the background of these two pictures. In order to make the backgrounds more similar, some other measures are also taken to do the slight improvement. There are three ways: First, adjust the parameters of the camera through software. Second, adjust resistors which lie on the LED-board to improve the brightness of LED. Third, normalize the pictures by special image preprocessing.

There are still another two things to be done before using this device. The one is using SURF [19] descriptor and algorithm to get the matching-matrix M. The other is using a self-adaptive algorithm to define a ROI (Regions of Interest). After getting the two pictures, the process to detect eyes involves five steps:

A. Preprocess

The obtained images should be transformed to gray ones at first. And then, the 940nm-image should be mirrored as the two symmetrical images (Fig. 8). At last, the related algorithm is designed to normalize the pictures for special preprocessing.

$$\text{ratio} = \text{mean}(850\_\text{img})/\text{mean}(940\_\text{img}) \quad (1)$$

The ratio is the ratio between the mean gray intensity of 850nm-image and 940nm-image.

$$f(x, y) = ratio * g(x, y) \quad (2)$$

The *f(x, y)* is the new 940nm-image after the normalization for primary 940nm-image *g(x, y).*

B. Matching

The matching-matrix is applied to do the transformation in terms of the 940nm-image. After the match, 940nm-image must be the same as the 850nm-image with only a little difference in pupils.

Before the experiment, SURF descriptor is applied to do the match through the formulation:

$$d(E_m, N_n) = \min_{n \in \{1,2,...\}} \left(\sum_{i=1}^{64} (E_{mi} - N_{ni}) \right) \quad (3)$$

After this, the parameters in matrix M are saved and have been loaded when we do the warp.

C. Subtraction

When subtraction from the 850nm-image to the 940nm-image is finished, a picture with some white zones is obtained.

D. Pupil detection

First, the gray intensity of the picture which lies outside the ROI is initialized as zero. By this way, the noises in the section which isn't ROI can be eliminated. Next, a self-adaptive threshold is adopted to remove the noise of ROI and detect the pupils as the following description:

$$g(x, y) = \begin{cases} 255 & if \quad g(x, y) > 0.75 * \max(g(x, y)) \\ 0 & else \end{cases} \quad (4)$$

The *g(x, y)* is the gray intensity of point *(x, y).*

E. Eye detection

If pupils' position is obtained in step D, eyes' position can be positioned just by calculating a center and radius of these white zones. If pupils' position isn't obtained, the former one should be temporarily used to get rid of eye closure. If pupils are still absent for some more seconds, it could be supposed that there is no person. Also, if circles collide with each other, just keep one and remove the others. In order to simplify the dealing progress, a rectangle zone is used to judge whether it is a new eye or not.

$$Y = \begin{cases} no & if \ |(new\_center(x) - old\_center(x))| < 10 \\ no & if \ |(new\_center(y) - old\_center(y))| < 10 \\ yes & else \end{cases} \quad (5)$$

Y is the arbiter designed with the geometrical structure of human's eye.

VI. EXPERIMENTS AND RESULT

With this device, two images with different brightness pupil are obtained, as shown in Fig. 8. The left one is the image with the reflected 940nm light entering into the CCD. The right one is the 850nm.

(a) the 940nm-image (b) the 850nm-image

Figure 8. The input images

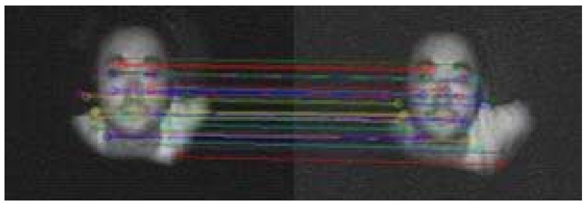

Figure 9. The SURF matching

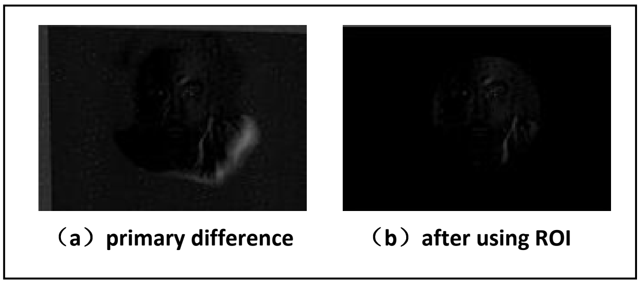

Figure 10. The substracted image

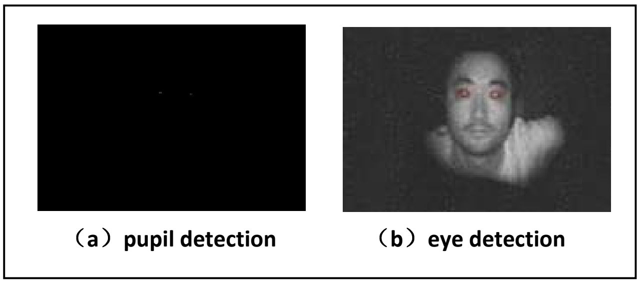

Figure 11. The detection

Use the images (Fig. 8) and the matching matrix M to match these two photos (Fig. 9). After the matching and the subtraction, then Fig. 10 (a) is obtained. There are still much useless noises, so the ROI detection is used to do a preprocessing. And the difference is obtained shown in Fig. 10 (b). In order to make the pupil detection, useless candidates can be eliminated through the whole threshold method. After that, get the position of the pupils as Fig. 11 (a) shows. At the end, calculate the center of the pupil and draw a circle as the detected eyes (Fig. 11 (b)).

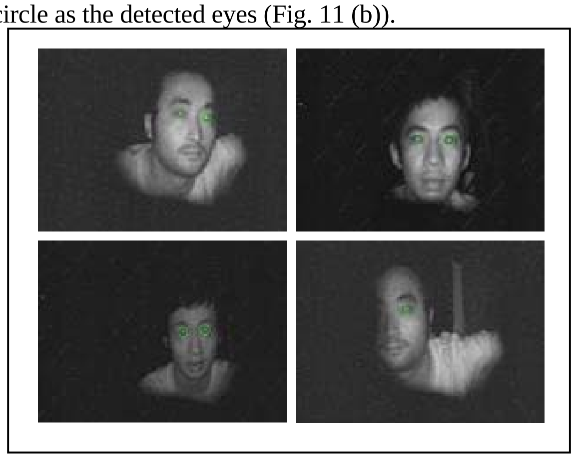

Figure 12. Some more eye-detecting result

VII. CONCLUSION

In this paper, 850-property is described and the experiments show that this phenomenon is not a random event. The phenomenon is applied together with red-eye effect in designing a new camera system and the system could help us get clearer pictures more easily even in some complex backgrounds in which some traditional image-analysis-based methods are not available. In future work, we'll attempt to improve the hardware and apply this technology to drowsy driver detection.

REFERENCES

[1] Richard Grace, Vicky E. Byme, Damian M. Bierman, Jean-Michel Legrand, David Gricourt, Robert K. Davis, James J. Staszewski and Brian Carnahan. A Drowsy Driver Detection System for Heavy Vehicles. Digital Avionics Systems Conference (DASC),1998.

[2] Antonio Haro, Myron Flickner and Irfan Essa. Detecting and Tracking Eyes By Using Their Physiological Properties,Dynamics, and Appearance. Coference on Computer Vision and Pattern Recognition (CVPR), 2000.

[3] C.H. Morimoto, D. Koons, A. Amir and M. Flickner. Pupil detection and tracking using multiple light sources. Image and Vision Computing, 2000.

[4] Zhiwei Zhu, Qiang Ji, Fujimura, K. and Kuangchih Lee. Combining Kalman filtering and mean sift for real time eye tracking under active IR illumination. Pattern Recognition (ICPR), 2002.

[5] Qiang Ji and Xiaojie Yang. Real-Time Eye, Gaze, and Face Pose Tracking for Monitoring Driver Vigilance. Real-Time Imaging, 2002.

[6] Arnon Amir, Lior Zimet, Alberto Sangiovanni-Vincentelli and Sean Kao.An embedded system for an eye-detection sensor. Computer Vision and Image Understanding, 2005.

[7] Carlos H. Morimoto and Marcio R.M. Mimica. Eye gaze tracking techniques for interactive applications. Computer Vision and Image Understanding (CVIU), 2005.

[8] Yan Chao, Wang Yuanqing and Zhang Zhaoyang. A Novel Real-Time Eye Detection in Human-Computer Interaction. Communications in Computer and Information Science (CCIS), 2011.

[9] Richard Youmaran and Andy Adler, Using Red-Eye to improve face detection in low quality video images. Electrical and Computer Engineering, 2006.

[10] Guestrin, E.D. and Eizenman, M. General theory of remote gaze estimation using the pupil center and corneal reflections. Biomedical Engineering, 2006.

[11] Jie Yang and Chunlin Shi. Eye Tracing in Real-time Fatigue Driving Monitoring System. Signal Processing (ICOSP), 2006.

[12] CHEN Chun bo,WANG Yuan qing.Eye detection based on red-eye effect. Computer Engineering and Applications, 2007.

[13] Yoshinobu Ebisawa, Kazuki Abo and Kiyotaka Fukumoto. Head-Free, Remote Eye-Gaze Detection System with Easy Calibration Using Stereo-Calibrated Two Video Cameras.Communications in Computer and Information Science (CCIS), 2011.

[14] Xia Liu, Fengliang Xu and Fujimura, K. Real-time eye detection and tracking for driver observation under various light conditions. Intelligent Vehicle Symposium, 2002.

[15] Beymer, D. and Flickner, M. Eye gaze tracking using an active stereo head. Coference on Computer Vision and Pattern Recognition (CVPR), 2003.

[16] Jun Wang and Lijun Yin. Detecting and Tracking Eyes Through Dynamic Terrain Feature Matching. Computer Vision and Pattern Recognition (CVPR), 2005.

[17] Zhiwei Zhu and Qiang Ji. Robust real-time eye detection and tracking under variable lighting conditions and various face orientations. Computer Vision and Image Understanding (CVIU), 2005.

[18] Xinguo Yu, Weicheng Han, Liyuan Li, Ji Yu Shi, and Gang Wang. An Eye Detection and Localization System for Natural Human and Robot Interaction without Face Detection. Lecture Notes in Computer Science (LNCS), 2011.

[19] Herbert Bay, Tinne Tuytelaars, and Luc Val Gool. SURF: Speeded Up Robust Features. European Conference on Computer Vision (ECCV), 2006

Published by Atlantis Press, Paris, France.