# Eye Control System Base on Ameliorated Hough Transform Algorithm

Jianbin Xiong, *Member, IEEE*, Weichao Xu, *Member, IEEE*, Wei Liao, Qinruo Wang, *Member, IEEE*, Jianqi Liu, and Qiong Liang

***Abstract*— This paper proposes an eye control system employing eye gaze tracking techniques that might be helpful for those limb disabled people with healthy eyes. Eye gaze tracking technique is attracting more and more research interest in recent years. With an aim to overcome the shortcomings of existing methods (e.g., high hardware complexity and low detection accuracy), we use the pupil-corneal reflection technique to develop an ameliorated Hough transform algorithm, which is the core unit of the proposed system. We also design a typing function as well as an efficiently blink detection function. With these functions, users can input numbers into the computer with their eyes only through a specifically designed head mount eye control device. Experimental results demonstrate that the proposed ameliorated Hough transform algorithm provides a satisfactory typing accuracy of 87%, much higher than its counterpart in the literature.**

***Index Terms*— Gaze tracking, head-mounted display, pupil position, hough transform algorithm.**

## I. Introduction

IN CHINA, the limb disabled population occupies a large percentage of the total Chinese population, amounting to about 24 million in 2006 according to the Chinese National Bureau of Statistics [1]. Due to their limb handicap, such vast amount of people cannot enjoy the convenience and entertainment of the ever advancing computer technology. With purpose of meeting the specific needs of these limb disabled people, in this paper we design an eye control system that might be useful for those limb disabled people with healthy eyes to interact with computers. The main idea is to employ eye gaze tracking technique as an interface of control the computer. In other words, this system purports to enable people "typing" by eyes instead of by hands.

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J. Xiong and Q. Liang are with the School of Computer and Electronics Information, Guangdong University of Petrochemical Technology, Maoming 525000, China (e-mail: 276158903@qq.com; liangqiong8362@qq.com).

W. Xu, Q. Wang, and J. Liu are with the Department of Automation, Guangdong University of Technology, Guangzhou 510006, China (e-mail: wangqr2006@gdut.edu.cn; wcxu@gdut.edu.cn; 45202851@qq.com).

W. Liao is with the University of Sheffield, Sheffield S10 2TN, U.K. (e-mail: 105019398@qq.com).

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Recently, eye gaze tracking has become one of the most interesting and important research topics because of its wide usefulness in various applications, such as Human Computer Interaction (HCI), Virtual Reality, Eye Disease Diagnosis, Human Behavior Studies, and so forth [2]. Early eye gaze tracking devices required physical contact with the user, such as placing a reflective white dot directly onto the eyes [3], or attaching a number of electrodes around the eyes [4]. The requirement of physical contact, while useful for improving tracking performance, is inconvenient to set up and thus limits their applicability in practice.

With development of technologies in microcomputers and video cameras, digital video based gaze tracking technology has become the mainframe method [5]–[14]. In contrast with the early techniques just mentioned, these new methods require no physical contact, and hence are suitable for the system proposed in this paper.

There are many advantages and disadvantages in the existing video based methods. Dodge and Cline successfully used the cornea reflection method to record the eye movement [4]. However, the accuracy is rather low because of the sensitivity to head movement. To improve the accuracy of Dodge and Cline's method, another eye tracker, called Generation-V Eye Tracker, was proposed based on the Dual-Purkinje image [8]. Although possessing a higher eye localization precision, this eye tracker involves expensive equipment and complicated algorithms, making it difficult to commercialize. In the late 1980s, the University of Virginia developed a commercial system, called Erica System, based on image processing as well as infrared television. Due to its high processing speed and strong practicality, the Erica System was quite popular among its users at that time. However, it was expensive and required special adapter to interface with a computer [15]. Recently, Zhang *et al.* developed a Tobii TX 300 eye movement tracker which is robust to interference caused by head movement [16]. Being capable of processing gazing data sampled up to 300Hz, this system satisfies some research requiring high sample frequency, such as glancing, correction glance, stare, change of pupil size and blink. However, similar to Erica System, it is also very costly and unaffordable for users with less purchasing power.

To overcome the shortcomings of existing methods mentioned above, this paper proposes a novel eye gaze tracking system with purposes of high tracking accuracy and low cost of implementation. This paper is organized as follows. Section II introduces the theoretical methods and

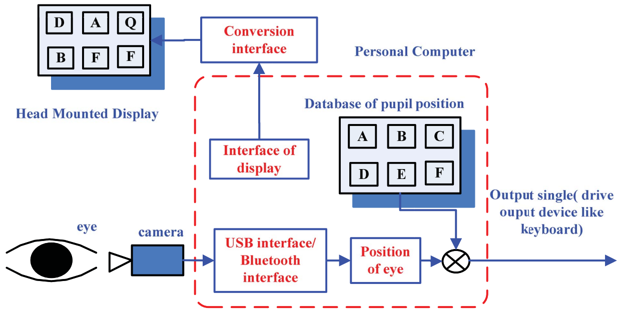



Fig. 1. The flowchart of the control hardware system based on pupil localization.

the system implementation. Section III illustrates the experiment results and analysis. Section IV describes system debugging and discussion. Finally, a conclusion is drawn in Section V.

## II. Theoretical Methods and System Implementation

### A. System Overview

Fig.1 depicts the hardware structure of the control system based on pupil localization. The personal computer to be controlled sends a 15-key soft keyboard on the screen of the head mounted display device. When the user watches the soft keyboard, the position of pupil center varies with respect to each key he/she stares at. At the same time, the eye images are captured and transmitted to the computer by a camera USB or Bluetooth. Using these eye images as input, the software then localize the pupil position employing a pupil cornea reflection method. With the relationship established through calibration between pupil position and the screen of head mounted display device, the gaze of the user is determined by an eyeball mapping model. The computer thus knows which key the user is looking at, and the type-in process of the specific key is then finished.

For comfort and convenience, the screen resolution of the head-mounted display is set to be 800*600, and the keyboard area is set to be about half the size of the screen. The number of keys should be larger than nine. The keyboard content should at least include different character keys, a deleting text key, symbol keys and a switch function key.

### B. Theoretical Methods

*1) The Hough Transforms Algorithm:* There are two important parts in the pupil-cornea reflection method, which are pupil detection and Purkinje image detection. At present, there exist many feasible algorithms in the area of human eye detection and pupil localization, such as the Hough transform algorithm, the deformable template method, the edge characters analysis method and the symmetry transformation method [6]. Being capable of extracting the comprehensive description parameters on the basis of local metrics, the Hough transform algorithm has good anti-jamming performance. Moreover, it also has high level of fault tolerance and robustness against

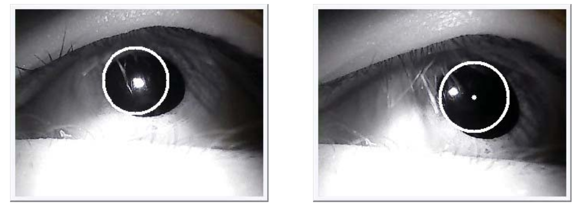


Fig. 2. The result of the Hough transform algorithm.

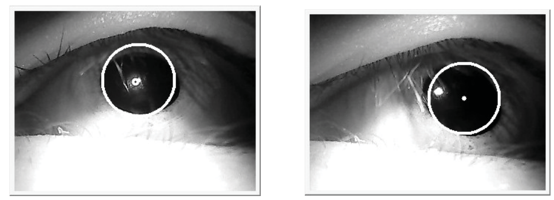


Fig. 3. The result of the ameliorated Hough transform algorithm.

discontinuities in the boundaries due to covering of other targets [7], [8]. Because of these advantages, we employ the Hough transform algorithm in our system as the major pupil localization method.

Now, we proceed to introducing the Hough transform algorithm [21]. To fully describe a circle

$$(x-a)^2 \quad + (y-b)^2 = r^2, \tag{1}$$

it is obvious that three unknown parameters (a, b, r) are to be determined. In other words, if we know at least three points on the same arc, we can identify the parameters (a, b, r) by solving

$$\begin{cases} (x_1-a)^2 + (y_1-b)^2 = r^2 \\ (x_2-a)^2 + (y_2-b)^2 = r^2 \\ (x_3-a)^2 + (y_3-b)^2 = r^2. \end{cases} \tag{2}$$

Using (1) and (2), the Hough transform algorithm can then transform the image domain into the parameter domain. Substituting the edge point set ($x_n$, $y_n$) into Eq. (2) successively and solving the equations, we can obtain the corresponding parameter set ($a_n$, $b_n$), Based on which a best likely parameter set containing the center coordinates and the radius of the circle is estimated by a voting mechanism. The computed circle center is called the Hough center. While possessing good fault tolerance and robustness performance, the Hough transform performs poorly for detection of non-standard circles. Due to the impact of the camera and eyelashes, most pupils in the pupil images are not perfectly circular. Consequently, the pupil detection of the Hough transform algorithm often makes mistakes.

To this end, we propose an ameliorated Hough transform algorithm to enhance the ability of the Hough transform algorithm .

*2) The Ameliorated Hough Transforms Algorithm:* The ameliorated Hough transform algorithm contains the coarse positioning method [22], the image capture method, the image filtering method, the Canny edge-detection method [24] and the Hough transform algorithm. The key idea is to combine together the coarse positioning method and the Hough transform algorithm [21]. The specific implementation will be described in the following section.

The accuracy of the ameliorated Hough transform algorithm is much better than the original Hough transform algorithm as can be seen from the comparison between Fig.2 and Fig. 3.

*3) The Coarse Positioning Method:* The purpose of this method is to scan for a coarse range of the pupil using a slide window in the binary image produced via the preprocessing module [22]. Since the area of a pupil occupies the darkest part in the image, the area containing a maximal number of 0 grayscale in the slide window is identified as that of the pupil. At the same time, the center of the corresponding slide window is marked as the coarse central position of the pupil.

*4) The Image Filtering Method:* The Gaussian smooth filter [23] with the Eq.(3) is used in the image filtering method. It has a good performance on reducing the random noise within the image and is helpful for the edge detection.

$$\mathrm{g(i,j)} = \mathrm{e}^{\frac{-(\mathrm{i}^2-\mathrm{j}^2)}{2\sigma^2}} \tag{3}$$

*5) The Canny Edge-Detection Method:* The Canny edge-detection method [24], [25] uses Gaussian one-step differentiation to calculate the gradients of an image by searching the partial max gradients of the image. The method detects a strong edge and a weak edge by the double-threshold method. The complete edge will be output when the strong edge connects to the weak one becoming the edge of the contour.

*6) The Purkinje Image Detection Method:* The detection method of the Purkinje image [12] is another important part of the pupil-cornea reflection method. In the gray eye image, a Purkinje image is a small and high grayscale glint on the pupil. It looks like an ellipse because of the angle of the camera and the infrared source. Therefore, it is reasonable to fit the edge of the Purkinje image by an ellipse, whose equation for is

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0. \tag{4}$$

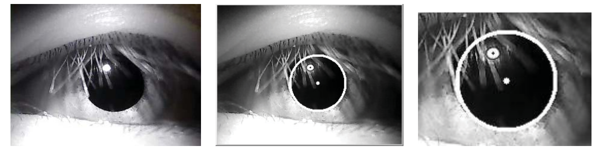
**The principle of the ellipse fitting method is:** Firstly, six points are selected randomly from the edge point set. Secondly, the ellipse parameters are calculated by the least-square method. Thirdly, the number of points which match the ellipse and the maximal matching point are calculated via traversing all the edge points. Fourthly, the best ellipse is chosen according to the voting mechanism. Finally, the center of the Purkinje image is obtained [12∼14].

**The principle of the least-square method is** [27]: Assuming the equation for ellipse is Eq. (4). To avoid zero solution, we set a constraint condition: A+C=1. With the edge point set from the edge detection, the minimum of the following equation

$$f(A,B,C,D,E) = \sum_{i=1}^{n} \left(Ax_i^2 + Bx_iy_i + Cy_i^2 + Dx_i + Ey_i + F\right)^2 \tag{5}$$

is solved to decide each system [28], which means that the following equation must exist:

$$\frac{\partial f}{\partial B} = \frac{\partial f}{\partial C} = \frac{\partial f}{\partial D} = \frac{\partial f}{\partial E} = \frac{\partial f}{\partial F} = 0. \tag{6}$$



(a) (b) (c)

Fig. 4. The effect of Purkinje image detection. (a) The initial eye image. (b) The detected Purkinje image. (c) The image enlarged from (b).


Fig. 5. Vuzix Warp 920VR Head Mount Display.

Therefore, we can obtain a system of linear equations. The parameter (A,B,C,D,E) and the center of the ellipse ($X_p$, $Y_p$) can be calculated by solving the equations [29].

It is noteworthy that both of the pupil localization and the Purkinje image detection are in essence circle detection techniques Fig.4.(c). In order to isolate the two methods, we design two ranges of detecting radius. It can be seen from the Fig. 4. (a) and (b). that these two methods can work alone well.

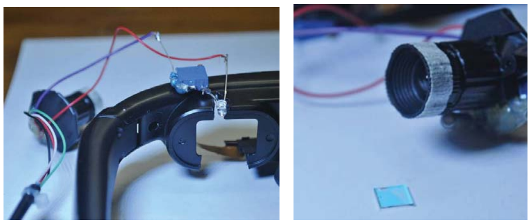
*7) Image Binarization:* The image is transformed into binary image with the following equation:

$$Pn = \begin{cases} 0, P_0 < P_{\mathrm{TH}} \\ 255, P_0 \geq P_{\mathrm{TH.}} \end{cases} \tag{7}$$

We assume that the threshold is $P_{TH}$ , the value of the previous pixel is $P_0$ , the value of the processed pixel is $P_n$.

*8) Blink Detection:* Blink is one of the crucial behaviors of optic action. Utilizing blink reasonably can make up the shortage of the optic function. A common blink detection method is the template matching method [30]–[32], which uses the eye-closed templates and eye-open templates to match the eye images. The advantages of the method are high accuracy and good flexibility. It is suitable for detecting blink in face images [33]. However, the disadvantages of it are complication, low processing speed and high hardware requirement. As this system only need to process eye images which are clear, we design a simple but effective blink detection method [34].

The main target of the method is to estimate whether the pupil and the Purkinje image are both disappeared. There are two flags in the coarse position method and the Purkinje image detection method, respectively. If either the pupil or the Purkinje image disappears, the respective flag will be set as disappearance status. Otherwise, they will be set as existence status. Once both flags are shown as disappearance status, an event of blink is identified. Note that it is necessary to set two flags because one of the flags may be changed to disappearance status by mistake for many reasons. Moreover, to avoid the extra blink detection caused by long time eyes closing, the method only confirms blink after both flags changing from disappearance to existence status.



(a) (b)

Fig. 6. The Camera and modified equipment. (a) The infrared emitter diode circuit. (b) The Philips SPC610CN Macro Lens.


(a) (b)

Fig. 7. Eye images captured by different cameras and under different light sources. (a) The normal eye image. (b) The eye image captured by infrared camera under an infrared source.

Fig. 8. The head mount eye control device.

### *C. Hardware Design and Implementation*

The device of the system is consisted of a display module, an infrared module and a camera module. The display module is the Vuzix Warp 920VR Head Mount Display (Fig. 5). The infrared module is an infrared emitter diode circuit Fig.6(a). The camera module is the Philips SPC610CN Macro Lens. The infrared filter in the camera was removed so as to enable the camera to capture infrared images Fig.6(a). Using an infrared source, the device does not have any impact on the user. Consequently, as can be seen from the infrared image, the iris part disappears so that the system can obtain clearer pupil images (Fig.7 (a)∼(b)). The photos of the device are shown in Fig. 8.

### *D. Software Design and Implementation*

The system uses the pupil cornea reflection method [17]–[19] to track gaze. Therefore, the main target of the system is to obtain a series of vectors from the Purkinje image center to the pupil center as eye-gaze direction parameters in real time. Then, the gaze of the user can be calculated by an eyeball mapping model. The main program includes the preprocessing module, the ameliorated Hough transform algorithm [20], the Purkinje image detection method, the blink detection method and the coordinates transform & calibration method. Furthermore, the ameliorated Hough transform method is the most important module of the main program and is the key to track gaze.

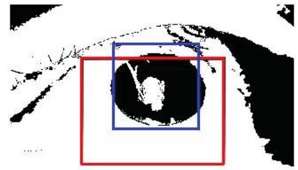


Fig. 9. The effect of the coarse positioning method.

In 2007, Liang and Houi [21] described a non-intrusive eye gaze tracking method based on Hough transform method. Their eye gaze tracking method could use a series of methods including the Hough transform algorithm to calculate the position of pupils in face images from video images. The accuracy of the method reached 90%. Moreover, its advantages are high processing speed, low hardware requirement and easy implementation. However, it had several drawbacks. Firstly, the detection effect of the Hough transform method was bad when the pupil was in some edge areas or partially covered by the eyelids. Secondly, the user could not move his head when he was detected. Thirdly, the method could only process video files not capture eye images from camera in real time. Consequently, to solve the above problems, this paper describes a new eye control system with the ameliorated Hough transform algorithm, which is the core of the system.

Firstly, the initial eye image from the camera is grayed and is binarized by the preprocessing module.

Secondly, the system utilizes the ameliorated Hough transform algorithm to detect the pupil center with the following steps:

1) The system starts the coarse positioning method [22] to process the image from the preprocessing module. A circle slide window with a diameter of 196 pixels is used to scan a limited area, the size of which is 320*240 (pixels), of the binary image obtained from the preprocessing module. Ideally, the area where the number of 0 grayscale in the slide window is the maximum will be the area of a pupil, if the size of the slide window is reasonable. At that time, the center of the slide window is the coarse position center ( $X_c$, $Y_c$ ) of pupil. The effect of the coarse positioning is shown in Fig. 9. For better illustration, we use a blue square to represent the slide window and a red rectangle to represent the limited area.

2) With the coarse position center ($X_c$, $Y_c$), we can obtain four corner coordinates of the pupil area. They are ($X_c-120$, $Y_c-120$), ($X_c+120$, $Y_c-120$), ($X_c-120$, $Y_c+120$), ($X_c+120$, $Y_c+120$). With the coordinates, the system can capture a square pupil area image with a side of 240 pixels from the gray eye image. The captured image is shown in Fig. 10.(a).

3) The pupil area image is successively processed by the image binarization method, the Gaussian smooth filter [23] and the Canny edge-detection method [24], [25] . The process is shown in Fig.7.(a)∼(d).

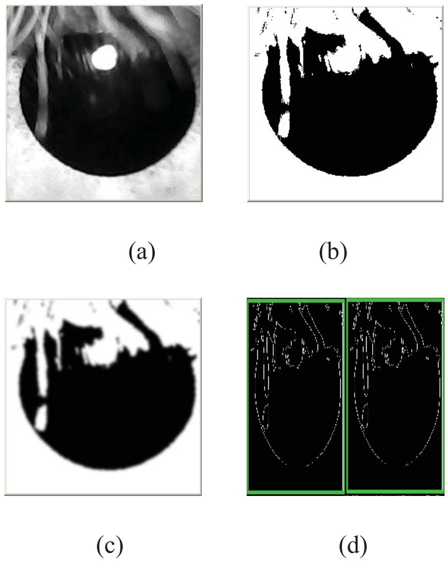



Fig. 10. Image capture, image filter and Canny edge-detection. (a) Captured pupil area image. (b) Binary image. (c) Gaussian smooth filtered image. (d) Canny edge-detected image.

Fig. 11. The detected Purkinje image.

Fig. 12. The vector from the Purkinje image center to the pupil center.

4) The edge point set is processed by the Hough transform algorithm [21]. The circle center computed by the algorithm is called the Hough center ($X_h$, $Y_h$).

5) The distance between the coarse position center ($X_c$, $Y_c$) and Hough center ($X_h$, $Y_h$) is analyzed. When the distance is in a pre-set interval, the coarse position center is chosen as the final pupil center ($X_f$, $Y_f$). Otherwise, the final pupil center ($X_f$, $Y_f$) is the average of the two centers. Hence, we can get Eq. (8).

$$\left(X_f, Y_f\right) = \begin{cases} (X_c, Y_c), \min \leq |(X_c, Y_c) - (X_h, Y_h)| \leq \max \\ \frac{(X_c, Y_c)+(X_h, Y_h)}{2}, \text{others.} \end{cases} \tag{8}$$

Thirdly, with the captured pupil image in the ameliorated Hough transforms method, the Purkinje image center ($X_p$, $Y_p$) is calculated by the Purkinje image detection method. It is shown in Fig.11.

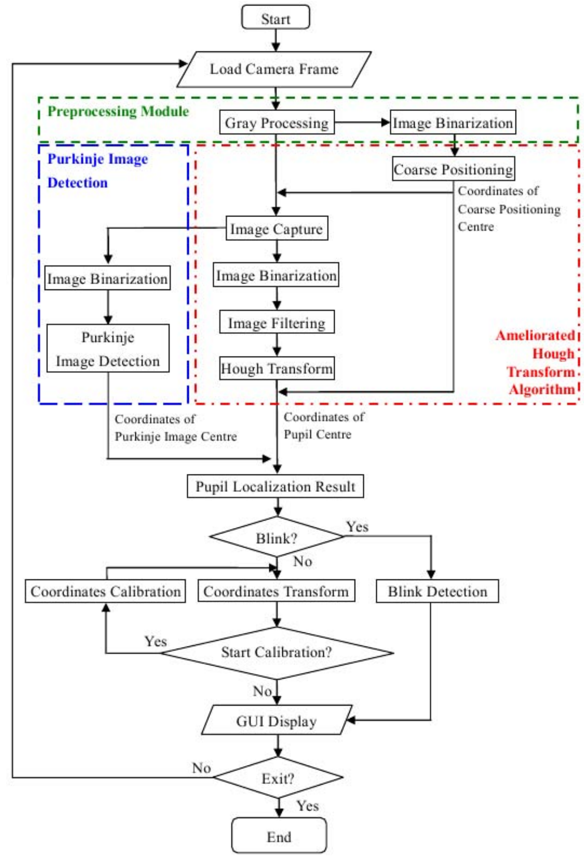



Fig. 13. The flow chart of the software.

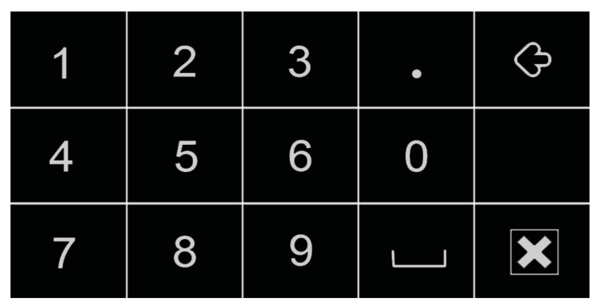



Fig. 14. Keyboard interface.

Fourthly, with the above two centers, a vector from ($X_p$, $Y_p$) to ($X_f$, $Y_f$) is transformed as the coordinates of the initial cursor in the keyboard image via a matching map of the coordinates transform method. The vector is shown in Fig.12.

However, the cursor does not work well now. Therefore, the user should start the calibration program first. After calibration, the cursor can move following the eye-gaze well. In order to detect eye-gaze in real time, after the above processing, the program will start to process a new image from preprocessing module again. So, the program is an infinite loop until the user chooses quit. If the user does not move the hardware after calibration, the calibration programs only need to be used once.

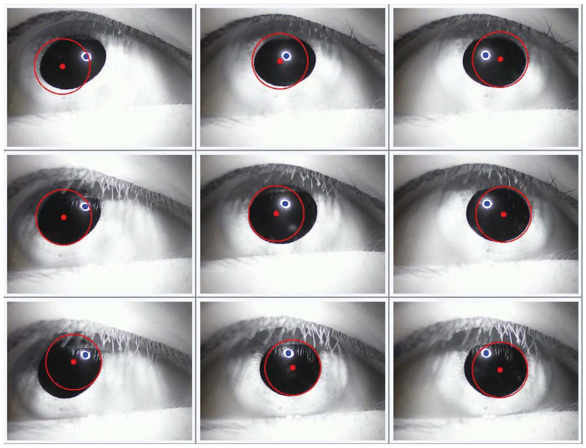


Fig. 15. The result of the Hough transform algorithm.

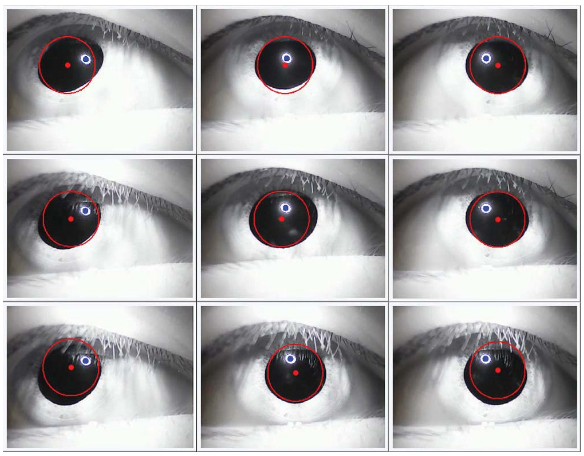


Fig. 16. The result of the coarse positioning method.

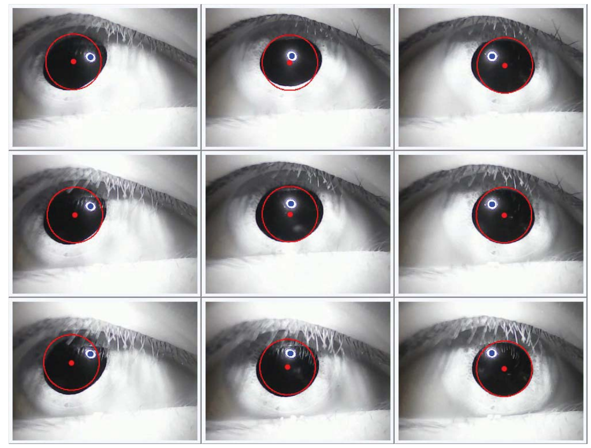


Fig. 17. The result of the ameliorated Hough transform algorithm.

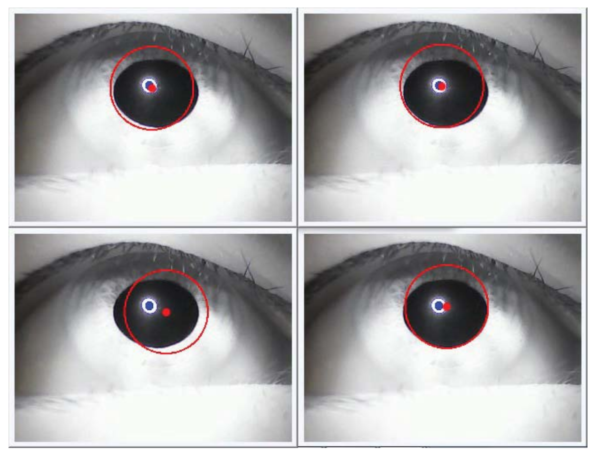


Fig. 18. The result of the Hough transform algorithm when the pupils are in the same position.

When the user gazes a key and blinks, a blue rectangle appears around the key. If the blink detection program has been started, a function related to the key will be started at the same time, such as typing a character or deleting a character. Otherwise, it does nothing. The flow chart of the software is shown in Fig.13.

## III. Experiment Results and Analysis

### *A. Test Result and Analysis of Localization Accuracy*

Several test results of a tester show if he stares a fixed point, the offset range of the keyboard curse will be almost a square area with a side of 140 pixels. When the fixed point gets closer to the center of the keyboard, the offset range of the keyboard curse is smaller. The smallest offset range is a square area with a side of 100 pixels. As the resolution ratio of the screen is 800*600 (pixels), this accuracy meets the design requirement of the system (a 15-key keyboard). And a 15-key keyboard is enough to implement the complete function of typing in numbers. The keyboard is shown in Fig. 14, consisting of 10 number keys (0-9), a 'full stop' key, a 'space' key, a deleting key, a keyboard function switch key and a blank key.

### *B. Test Result and Analysis of Typing*

The test result shows that the average typing speed of the tester is around 10 numbers per minute. The average accuracy of typing is 87%. Furthermore, the main errors mostly happen when the tester staring at the keys on the edge. However, the average accuracy of typing is 98%, when the tester stares the key '6'. Moreover, we find that the accuracy of typing is mainly depended on the pupil detection method and the coordinates transform method. In addition, the typing speed is mainly affected by the system processing speed and the camera frame rate.

### *C. Test Result and Analysis of the Pupil Detection*

The test results show the improvement of the ameliorated Hough transform algorithm. When the tester stares at 9 different points of the screen, the detection results of the Hough transform algorithm, the coarse positioning method and the ameliorated Hough transform algorithm are shown in Fig.15 and Fig.16, respectively. It is obviously that the detection of the Hough transform algorithm is inaccurate. However, with the help of the coarse positioning method and several other methods, the performance of the ameliorated Hough transform algorithm is much better than that of the others. As shown in

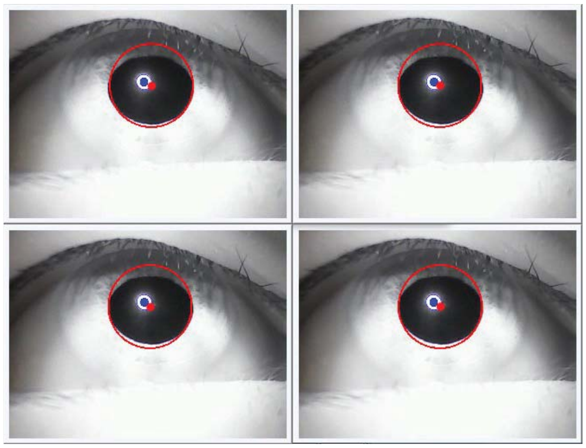
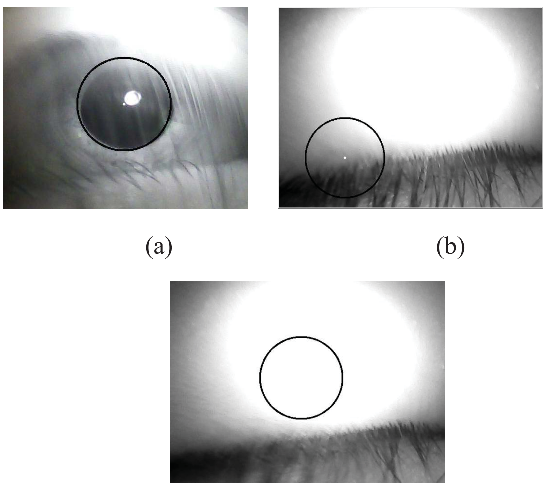


Fig. 19. The result of the ameliorated Hough transform algorithm when the pupils are in the same position.



(a) (b) (c)

Fig. 20. Error processing of blink. (a) The moment before closing eye. (b) The moment when error happens. (c) The effect of error processing.

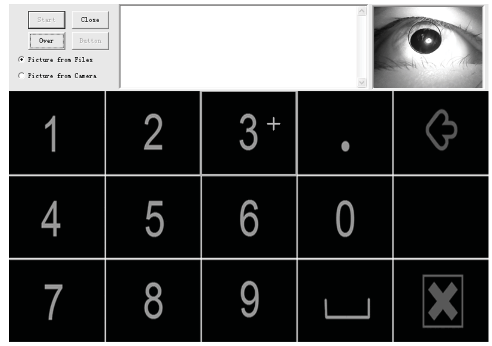



Fig. 21. Picture (1) of the unstable coordinates of pupil.

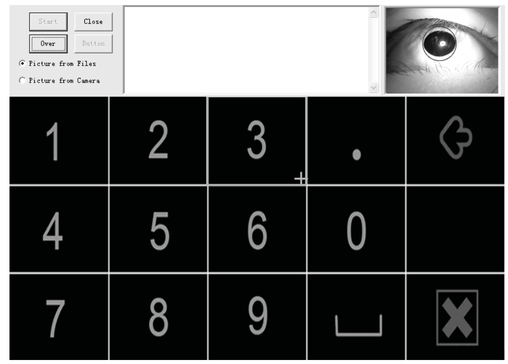



Fig. 22. Picture (2) of the unstable coordinates of pupil.

Fig.17, the detected pupil centers (the red points) are very close to the real centers. Moreover, the unstable detection of the Hough transform algorithm is shown in Fig.18. In these pictures, although the pupils are in the same position, the detected pupil centers are different. However, as can be seen from Fig.19, the result of the ameliorated Hough transform algorithm is more stable. The detected pupil centers are almost in the same position.

Furthermore, the accuracy of the ameliorated Hough transform algorithm reaches 3°, which can implement using eyes to control typing in numbers via a 15-key keyboard.

## IV. System Debugging and Discussion

*1) Error Processing of Blink:* When blink happens, the pupil area becomes small quickly and the shape of the pupil image changes quickly, which might lead to wrong localization. As a result, wrong pupil center coordinates and wrong keyboard curse coordinates are detected. The picture of the error is shown in Fig.20.(a)∼(b). As can be seen from Fig. 20(b), when the eye closes, the detected pupil center shifts for a long distance, which makes the blink detection function record an incorrect gaze point.

**Solution:** The center coordinates of pupil are incorrectly processed. As the Purkinje image disappears at the beginning of blink, the movement of the pupil center, which is larger than a threshold, is ignored after the Purkinje image disappears. Consequently, the coordinates of pupil center remain fixed during blink. Otherwise, to avoid impacting the normal curse movement, the movement of the pupil center is not ignored when the Purkinje image exists. The effect of the solution is shown in Fig.20.(c).

*2) The Problem of the Unstable Pupil Center Localization:* Science research shows that the position of a pupil is unconsciously unstable, when a human stares to a point. Since the brain can correct the shake, a person cannot feel it. However, as to pupil localization methods, it means that the coordinate of the pupil center shakes following the pupil, which leads to the decrease of localization accuracy. Meanwhile, the eye muscles and eyelid may move unconsciously when the user stares a point on the keyboard of the system. As the pupil localization method is sensitive to the change of the pupil, the coordinates of the pupil localization center become unstable. From Fig.21 to Fig.22, it can be seen from the up-right eye images that the pupils remain stable, but the coordinates of the calculated pupil center jump frequently between the two positions shown in the two pictures.

**Solution:** Filter processing the coordinates of the pupil center calculated by the pupil localization method. The power function model is used to filter the data. As shown in Fig. 23,

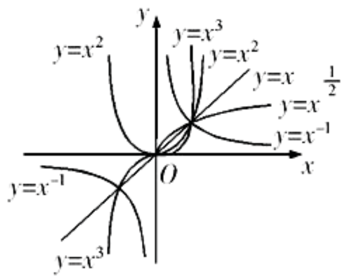



Fig. 23. The curve chart of power function.

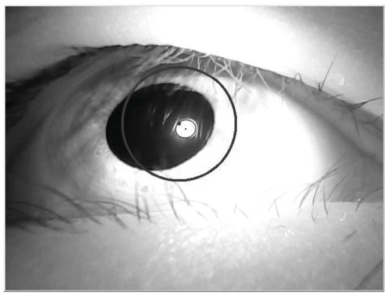


Fig. 24. The movement delay.

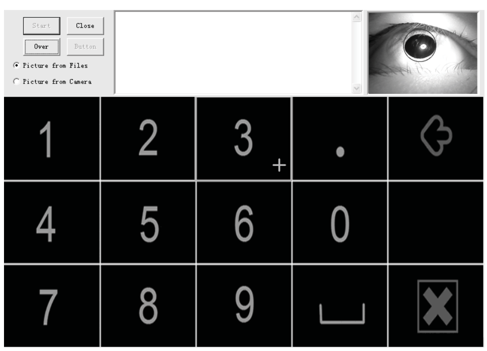



Fig. 25. Picture (1) of the stable coordinates of pupil.

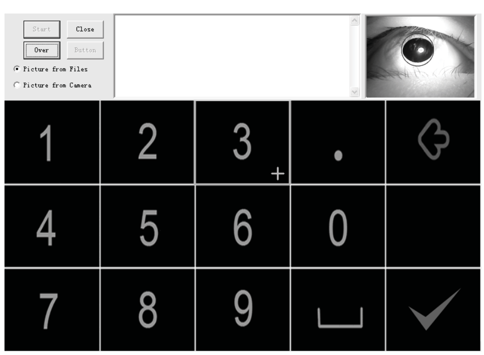



Fig. 26. Picture (2) of the stable coordinates of pupil.

the power function is

$$y = x^{a}. \tag{9}$$

When 'a' is larger than 1, the curve of the function is a first quadrant increasing function with an increasing slope. This model is chosen in filter processing. To begin with, a confidence interval and three time points are set. $T_o$ stands for initial time, $T_1$ and $T_2$ represent two successive time points after $T_0$, $P_0$ to $P_2$ respectively represent the coordinates of $T_0$ to $T_2$. Then, if $P_1$ is in the confidence interval of $T_0$, the distance between $P_0$ and $P_1$ will be shown as $M_1$ percent of the original one and a new $P_1$ will be obtained. Furthermore, if $P_2$ is in the confidence interval of $T_1$, the distance between $P_1$ and $P_2$ will be remained. However, if any $P_{n+1}$ is not in the confidence interval of $P_n$ , the distance between $P_n$ and $P_{n+1}$ will be shown as $M_2$ ($M_1 > M_2$) percent of the original one and a new $P_{n+1}$ will be obtained.

The bigger the confidence interval is, the more unstable the coordinates of the pupil center are. On the contrary, the smaller the confidence interval is, the more serious the movement delay of pupil center is and the smaller the movement range is. The movement delay of pupil center is shown in Fig. 24. Several tests show that the best effect is when the confidence interval is 2% of the height of the eye image, $M_1$ is 30 and $M_2$ is 5. As can be seen from Fig. 25 and Fig. 26, with the filter processing, the coordinates of the pupil localization center are more stable than before.

## V. Conclusions

This paper designs an eye control system using the pupil-cornea reflection method, the ameliorated Hough transform algorithm and an efficient blink detection method, with purpose of meeting the specific needs of those limb disabled people. The pupil localization accuracy reaches 3°, which can implement using eyes to control typing in numbers via a 15-key keyboard, and the average accuracy of typing reaches 87%.

However, this system still has many shortages. Consequently, the next step of our work is:

Firstly, improve the pupil localization method in order to enhance the localization accuracy. Secondly, improve the calibration method to make the coordinates transform more accurate. Thirdly, with the development of the pupil localization, raise the key number up to more than 30 to implement typing in all the English letters. Fourthly, transplant the system from PC platform to the embedded system platform.

With the improvement of eye gaze tracking and hardware, this head mount eye control system can play an important role in helping the limb disabled people with healthy eyes to interface with the computers via a soft keyboard. Moreover, the methods developed can be applied to many other fields including medicine, military, traffic, just to name a few.

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**Jianbin Xiong** (M'12) was born in Hunan, China, in 1976. He received the B.E., M.A., and Ph.D. degrees from the Guangdong University of Technology, Guangdong, China. He is now with the Department of Computer and Information, Guangdong University of Petrochemical Technology, Guangdong.

His current research interests include signal processing, image processing, information fusion, and computer applications.

**Weichao Xu** (M'06) received the B.Eng. and M.Eng. degrees in electrical engineering from the University of Science and Technology of China, Hefei, China, in 1993 and 1996, respectively, and the Ph.D. degree in biomedical engineering from the University of Hong Kong, Hong Kong, in 2002. He is currently with the School of Automation, Guangdong University of Technology, Guangdong, China, as a Professor.

His current research interests include the areas of mathematical statistics, machine learning, digital signal processing, and computer applications.

**Wei Liao** was born in Guangzhou, China, in 1989. He received the B.E. degree from the Guangdong University of Technology, Guangdong, China. He is currently pursuing the M.A. degree at the University of Sheffield, Sheffield, U.K.

His current research interests include wireless communication, image processing, and computer applications.

**Qinruo Wang** (M'09) was born in Hainan, China, in 1958. He received the B.E. degree from the Guangdong University of Technology, Guangdong, China, and the M.A. degree from Zhejiang University, Zhejiang, China. He is currently with the Faculty of Automation, Guangdong University of Technology, as a Professor, and an Instructor, working with Ph.D. students.

His current research interests include automatic equipment and techniques, mechatronics, and automatic network control.

**Jianqi Liu**, photograph and biography are not available at the time of publication.

**Qiong Liang**, photograph and biography are not available at the time of publication.