Semi-dynamic Calibration for Eye Gaze Pointing System based on Image Processing

Kohichi Ogata and Kohei Matsumoto
Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan

Keywords: Eye Gaze, Iris, Calibration, Image Processing.

Abstract: In this paper, we propose two semi-dynamic calibration methods for compensating for user's head movements for an eye gaze pointing system. Since the user perceives degradation in pointing accuracy during use, an effective compensatory calibration by the user which does not require additional apparatus or high cost calculation can be a useful solution for the problem. The proposed semi-dynamic calibration methods lead the user to gaze at 1 or 3 points on the computer screen and reduce the gap between the true eye gaze direction and the position of the mouse pointer. Experimental results showed that the proposed methods were capable of pointing the mouse pointer within 20 pixels at a distance of about 60 cm between the user and the display.

1 INTRODUCTION

Eye gaze interface systems have the potential to be useful multimedia tools and related research and development have been continued (Young and Sheena, 1975) (Hutchinson et al., 1989) (Wang and Sung, 2002). However, they still have not been spread to our daily lives because of their expensiveness and complexity.

We have been developing an eye gaze detection system by using image processing technique without infrared light sources. In the system, the eye gaze direction is estimated by detecting the center of the iris from an eye image obtained with a miniature visible light camera. The system is capable of a real-time processing of 30 fps for 320 x 240 pixels with an accuracy of 0.6 and 1.3 degrees in horizontal and vertical directions, respectively (Yonezawa et al., 2008b) (Yonezawa et al., 2008a) (Yonezawa et al., 2010).

In eye gaze detection systems, user's head movements during long-term use cause detection errors. This problem causes unwanted positioning of the mouse pointer in spite of user's effort. Therefore, compensation for the troublesome movements is necessary to reduce the related errors. One of the solutions of the problem is to monitor head related movements with multiple cameras (Talmi and Liu, 1999) (Yoo and Chung, 2005). Other method requires four or more infrared light sources (Ko et al., 2008). However, a compensation method, which does not require additional apparatus or calculation for direct detection of the head movements, can be a useful solution to prevent the system from being complex. In an eye gaze driven mouse-pointing system, the user perceives degradation in pointing accuracy through the discrepancy between the true eye gaze direction and the position of the mouse pointer. In this paper, we propose two semi-dynamic calibration methods for compensating for the discrepancy mainly caused by user's head movements.

2 SYSTEM OVERVIEW

2.1 System Configuration

Figure 1 shows an overview of the system. The system consists of a small color video camera (Kyohritsu JPPCM25F 1/3 inch CMOS 0.25 Mpixel) and a desktop computer (CPU: Pentium4 3.2 GHz, MEMORY: 1 GB, OS: Windows XP) with an image capture board (Imagination PXC200). The camera is attached on the user's goggles. A computer display and a 20-W fluorescent table lamp are located in front of the user. A chin support is used to produce a rest position.

2.2 Iris Center Detection and Calibration

Figure 2(a) shows an example of detecting the contour of the iris from an eye image obtained with the

Ogata K. and Matsumoto K..
Semi-dynamic Calibration for Eye Gaze Pointing System based on Image Processing.
DOI: 10.5220/0004063602330236
In *Proceedings of the International Conference on Signal Processing and Multimedia Applications and Wireless Information Networks and Systems* (SIGMAP-2012), pages 233-236
ISBN: 978-989-8565-25-9

camera. The two green arcs indicate parts of the iris contour and the green dot indicates the center of the iris. These are obtained by circular pattern matching (Yonezawa et al., 2008b). Figure 2(b) shows five calibration points to be shown on the display screen in a calibration process in which a mapping function between the detected iris centers and the calibration points is calculated. In Figure 2(a), five iris centers which correspond to the five calibration points in Figure 2(b) are also shown as red dots.

Figure 3 shows an example of calibration vectors as a mapping function. An eye gaze direction is estimated by linear interpolation using the detected iris center and the calibration vectors on the eye image. We used a calibration method by (Fukushima et al., 1999).

3 SEMI-DYNAMIC CALIBRATION

Although a chin support is used as a positional reference and to reduce the head movements of the user, it is necessary to introduce the mechanism of compensation for the troublesome movements mainly caused by the head movements into our system for long-term use. Such a mechanism may lead the system which is free from the chin support in the future.

Figures 4 and 5 show overviews of two proposed semi-dynamic calibration methods. In the semi-dynamic calibration shown in Figure 4 (Method 1), three icons which correspond to three types of modification of the mapping function appear on the screen after user's eye blinking with intention. These three icons correspond to expansion (left icon), parallel translation (middle icon) and reduction (right icon) of the mapping vectors shown in Figure 3, respectively. The user can select an icon depending on the mismatch between the present location of the mouse pointer and one which the user intends to locate on the screen. In this Method 1, the mapping function is modified globally, i.e., on the whole of the display screen.

In contrast, in the semi-dynamic calibration shown in Figure 5 (Method 2), two calibration vectors which cover one of the quarter areas having an eye gaze point are modified. In this case, since the rough eye gaze point on the screen is known, two vectors to be modified can be automatically determined. This modification mode is activated by the user's eye blinking with intention and the user gazes at three points which form the beginning and end points of the two calibration vectors. This method modifies the mapping function locally and requires less pro-

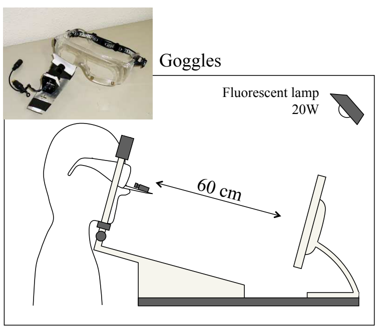


Figure 1: Overview of the eye gaze pointing system.

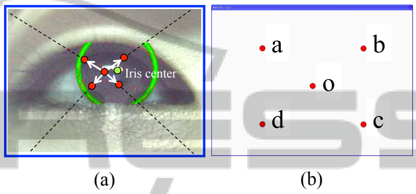


Figure 2: Detection of the contour of the iris and target points in the calibration.

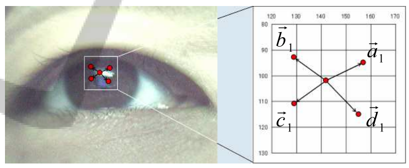


Figure 3: Example of calibration vectors as a mapping function.

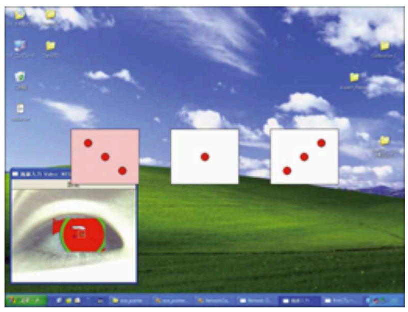


Figure 4: Semi-dynamic calibration for global modification of the mapping function (Method 1).

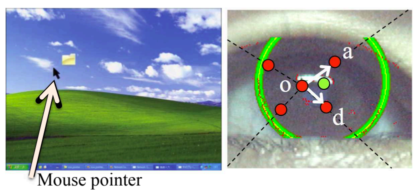


Figure 5: Semi-dynamic calibration for local modification of the mapping function (Method 2).

cedure steps than Method 1. The user can activate the two modification modes above at any time by the eye blinking of one second or above.

4 EXPERIMENTS

Experiments for evaluating the proposed methods were performed for five subjects with normal eyesight. The experimental setup is the same as Figure 1. A 17-inch display with 1024 x 768 pixels was placed in front of the subject at a distance of about 60 cm. Figure 6 shows flowcharts of the experiments. The experiments consist of three stages: Experiment I, II and III. In Experiment I, the usual calibration was performed and the related parameters were stored for later use in Experiment II and III. After the calibration, the subject was asked to free his or her head from the chin support and to place it again. After that, the subject was asked to gaze at 25 target points that randomly appear one after another on the screen. In Experiment I, a mouse pointer was not displayed on the screen to evaluate the original accuracy of the eye gaze detection with avoiding user's adjustment. The accuracy for each target point was calculated from image data of 30 frames after the subject pressing a space key on the keyboard. The experiment was followed by Experiment II and III and the stored calibration parameters were used at the beginning of each experiment to reproduce the same calibration condition as Experiment I. After that, the subject was asked to move the mouse pointer to 25 target points that randomly appear one after another. The pointing accuracy for each target point was calculated from image data of 30 frames in the same way in Experiment I. In experiment II and III, the subjects used the semi-dynamic calibration Method 1 and 2 respectively, when necessary.

Figure 7 shows examples of pointing accuracy for Subject 3. In each figure, the arrangement of the 25 target points on the screen is shown as red dots. The estimated eye gaze points based on the iris detection are shown as mesh points. Figure 7 (a) shows extremely large errors and suggests that it is extremely difficult to place the pointer because of the large discrepancy even if the pointer is displayed. In contrast, both the semi-dynamic calibration methods Figure 7 (b) and (c) show quite good pointing accuracy.

Table 1 shows the pointing accuracy for all the subjects. Each value shows the average over the 25 target points. These results suggest that the pointing accuracy using the semi-dynamic calibration methods is within 20 pixels in distance which is enough for pointing an icon in regular size. The average numbers of applying the method for all the subjects were 8.4 and 7.2 times for Method 1 and 2, respectively. Questionnaires for assessing the usability showed the easiness and effectiveness of the proposed methods.

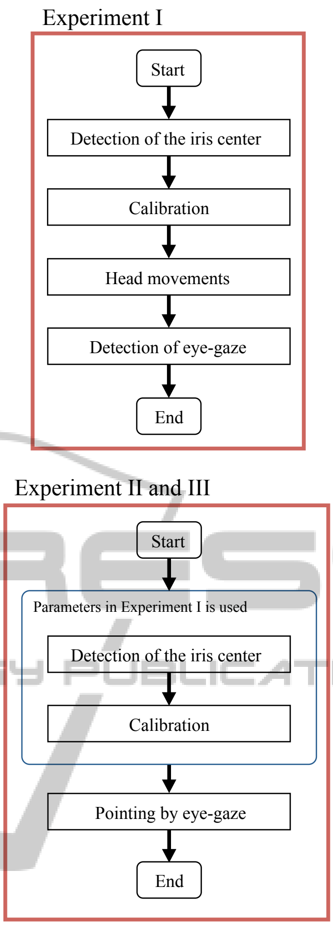


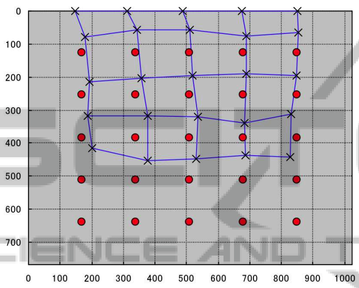
Figure 6: Flowcharts for experiments.

5 CONCLUSIONS

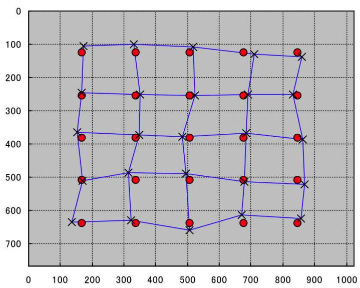
In this paper, semi-dynamic calibration methods for eye gaze pointing system were proposed for compensation for user's head movements. Experimental results showed that the proposed methods were capable of pointing the mouse pointer within 20 pixels at a distance of about 60 cm between the user and the display. These results suggest that the proposed methods are effective solutions with a reasonable accuracy in practical use preventing the system from being complex with additional apparatus or calculation for direct detection of the head movements.

Table 1: Results of pointing accuracy.

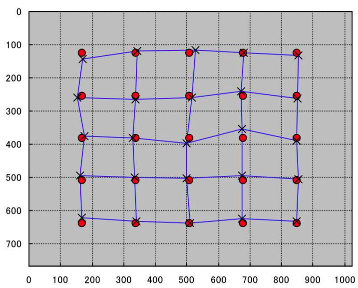
@	Accuracy [pixels]					
	Method 1			Method 2		
Subjects	Horizontal	Vertical	Distance	Horizontal	Vertical	Distance
Subject 1	10.8	10.9	17.2	10.2	10.8	16.1
Subject 2	7.6	9.5	13.5	7.2	10.8	14.5
Subject 3	12.7	11.8	19.3	5.5	9.8	12.1
Subject 4	10.9	10.5	16.6	9.5	10.9	16.3
Subject 5	16.9	14.5	25.1	15.7	18.6	28.6
Average	11.8	11.4	18.3	9.6	12.2	17.5



(a) Without semi-dynamic calibration



(b) With semi-dynamic calibration Method 1



(c) With semi-dynamic calibration Method 2

Figure 7: Examples of pointing accuracy for Subject 3.

ACKNOWLEDGEMENTS

Part of this work was supported by Grant-in-Aid for Scientific Research (C) from the Ministry of Education, Science, Sports and Culture, Japan.

REFERENCES

Fukushima, S., Arai, T., Morikawa, D., Shimoda, H., and Yoshikawa, H. (1999). Development of eye-sensing head mounted display. *Trans. of the Society of Instrument and Control Engineers*, 35:699–707.

Hutchinson, T. E., White, K. P. J., Martin, W., Reichert, K. C., and Frey, L. A. (1989). Humancomputer interaction using eye-gaze input. *IEEE Transactions on Systems, Man, and Cybernetics*, 19:1527–1534.

Ko, Y., Lee, E., and Park, K. (2008). A robust gaze detection method by compensating for facial movements based on corneal specularities. *Pattern Recognition Letters*, 29:1474–1485.

Talmi, K. and Liu, J. (1999). Eye and gaze tracking for visually controlled interactive stereoscopic displays. *Signal Processing: Image Communication*, 14:799–810.

Wang, J. and Sung, E. (2002). Study on eye gaze estimation. *IEEE Transactions on Systems, Man, and Cybernetics-Part B:Cybernetics*, 32:332–350.

Yonezawa, T., Ogata, K., Matsumoto, K., Hirase, S., Shiratani, K., Kido, D., and Nishimura, M. (2010). A study on reducing the detection errors of the center of the iris for an eye-gaze interface system. *IEEJ, 130-C*, 3:442–449.

Yonezawa, T., Ogata, K., Nishimura, M., and Matsumoto, K. (2008a). Development of an eye gaze interface system and improvement of cursor control function. In *Proceedings of International Conference on Signal Processing and Multimedia Applications (SIGMAP 2008)*. SciTePress.

Yonezawa, T., Ogata, K., and Shiratani, K. (2008b). An algorithm for detecting the center of the iris using a color image and improvements of its processing speed. *IEEJ, 128-C*, 2:253–259.

Yoo, D. H. and Chung, M. J. (2005). A novel non-intrusive eye gaze estimation using cross-ratio under large head motion. *Computer Vision and Image Understanding*, 98:25–51.

Young, L. and Sheena, D. (1975). Survey of eye movement recording methods. *Behavior Research Methods and Instrumentation*, 7:397–429.