DEVELOPMENT OF AN EYE GAZE INTERFACE SYSTEM AND IMPROVEMENT OF CURSOR CONTROL FUNCTION

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Abstract: This paper introduces an eye gaze interface system for controlling a mouse cursor on the computer display. The system consists of a small video camera to capture an eye image and a computer to detect the eye gaze from the image and to calculate the position of the cursor to be displayed depending on the detected eye gaze. In order to develop an easy-to-use system, consideration of involuntary and voluntary eye blink is necessary for practical use. Improvement of the stability of eye gaze-controlled cursor movement is also important. In this paper, smooth cursor control using a moving average filter and detection of involuntary and voluntary eye blink are described. The experiments show the usefulness of the proposed methods for quick and stable mouse cursor control. In the experiment of cursor pointing accuracy, distances between the target and the cursor point are about 30 pixels in horizontal direction and 20 pixels in vertical direction.

1 INTRODUCTION

Computers have become popular tools in daily life. Human computer interfaces using eye gaze have been developed for user convenience (Hutchinson, White, Martin, Reichert & Frey, 1989; Kim & Ramakrishna, 1999; Porta, 2002; Wang & Sung, 2002; Young & Sheena, 1975). Eye gaze human computer interfaces can provide a useful method for people with severe motor disabilities to operate a computer (Cleveland, 1994; Ito, Sudoh & Ifukube, 2000; Kanou, Inoue, Kobayashi, Kawamura & Nakashima, 2002). However, such systems are so expensive that the systems are not widely used for disabled people.

We have developed an eye gaze interface system with the aim of low cost and easy operation. This system consists of a small video camera attached on goggles, a computer with a color image capture board, and software. In this paper, improvement of the system to achieve quick and stable mouse cursor control is described. In Section 2.1, we describe hardware system. In Section 2.2, we show the procedure to detect the eye gaze position on the display from the eye image. In Section 3.1, we explain a moving average filter for smoothing mouse cursor movement. In Section 3.2, the experiment on the moving average filter of mouse cursor movement and the experimental results are shown. In Sections 4.1 and 4.2, we describe detection of eye blink and mouse cursor control during eye blink.

2 SYSTEM CONFIGURATION

2.1 Hardware Configuration

The system consists of a small color video camera (Kyohritsu JPP-CM25F 1/3inch CMOS 0.25 Mpixel) and a desktop computer (CPU: Pentium4 3.2GHz, MEMORY: 1GB, OS: Windows XP) with an image capture board (Imagination PXC200). The system is capable of processing 320 x 240 pixels at a frame rate of 30 fps. Figure 1 shows the small video camera attached on the goggles. Figure 2 shows an experimental environment.

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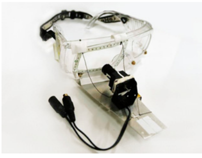

Figure 1: Goggles with a video camera attached.

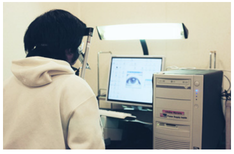

Figure 2: Environment of eye gaze detection experiment.

The outline of the data processing is as follows:

(1) Filtering in HSI color space to detect the region having an iris in the captured image frame.
(2) Determining the diameter of a ringshaped template to be pattern matched with the contour of the iris from an initial image frame.
(3) Determining the center of the iris as the center of the ringshaped template after pattern matching.
(4) Mapping the detected center of the iris onto the position of the mouse cursor on the display.

Through these processes, the user is able to control the position of the mouse cursor with his/her eye gaze. The mapping vector used in step (4) is determined from a prior calibration procedure.

Figure 3 shows two examples of the iris detection. In each example, the ringshaped template shows a good match with the contour of the iris. Its center (+) is also shown in the figure. The mean values of detected error on the 25 target points on the display over the five subjects are 1.78 degree in horizontal direction, 1.82 degree in vertical direction respectively. These values are almost equal to the resolution of other tracking system (Yonezawa, Ogata & Shiratani, 2008).

3 MOUSE CURSOR CONTROL BY MOVING AVERAGE

3.1 Moving Average Filter

In our system, a pixel on the image frame having eye image corresponds to about 20 pixels on the computer display in length. Therefore, fluctuation of the detected center of the iris can cause difficulty in controlling the mouse cursor. In order to reduce such a situation, a moving average filter (MAF) shown as Eq. (1) was introduced in the system.

$$y(t) = \frac{1}{m}\sum_{i=o}^{m-1} x(t-i) \qquad (1)$$

where $x(t)$ is the input data, $y(t)$ is the output data, and m is the number of frames to be used.

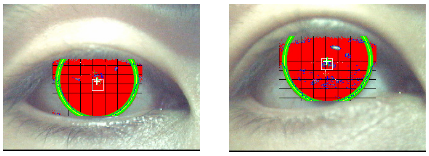

Figure 3: Examples of detection of the center of the iris using pattern matching.

3.2 Experimental Setup

In order to evaluate the effects of the moving average filter on the cursor control, the experimental setup shown in Figure 4 was used. Illuminance near the subject's eyes is about from 250 to 400 lx. An LCD –display of 17 inch and 1024 x 768 pixels was used. Five subjects with normal eyesight were participated in the experiment. The number of frames used in moving average was 30. The experimental procedure is as follows:

(1) One of the nine targets shown in Figure 5 is randomly selected and displayed.
(2) A subject moves the mouse cursor into the target through his/her eye gaze.
(3) The subject keeps the position of the mouse cursor on the target for two seconds.

This trial was applied five times to a randomly selected new target for each subject. Total time for the five trials and the standard deviation of the mouse cursor movement for each subject were evaluated.

Figure 6 shows the total time for the five trials averaged over the five subjects. The effect of moving average filter is shown as the reduction of time for the mouse cursor control. Table 1 shows the standard deviations of the mouse cursor movement within the each target for two seconds averaged over the trials and the subjects. The standard deviations for the case using the moving average filter are less than those for the case without the filter in both directions.

Because the moving average filter was useful for the mouse cursor control, the number of frames used in filtering was evaluated to obtain the optimum number. The experimental procedure was the same as used in the previous experiment and 10, 20, 30, and 40 frames were used in the filtering. Two subjects with normal eyesight were participated in the experiment.

Figure 7 shows the total time for the five trials averaged over the two subjects. Table 2 shows the standard deviations of the mouse cursor movement averaged over the trials and the subjects. As shown in the figure and the table, the moving average filter with 20 frames is most effective for quick and stable cursor control. Therefore the filtering function is installed on our interface system.

4 DETECTION OF EYE BLINK AND MOUSE CLICK FUNCTION

4.1 Detection of Eye Blink

Involuntary eye blink is inevitable while use of the system. During the eye blink, it is difficult to detect the contour of the iris because of occlusion caused by eyelid. To avoid failure in the detection of the contour and cursor control, a detection algorithm must be considered. In this section, the outline of the algorithm is described.

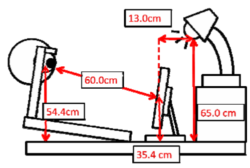

Figure 4: Experimental environment.

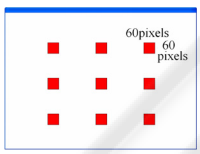

Figure 5: Nine target points on the display.

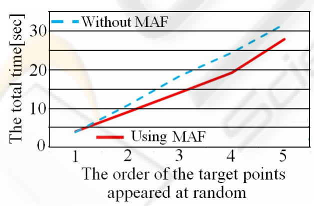

Figure 6: The total time for pointing the mouse cursor onto the five targets on the screen by eye gaze.

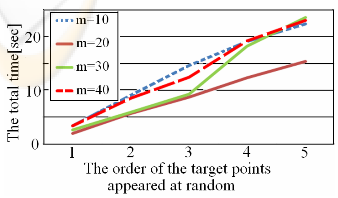

Figure 7: The total time for pointing the mouse cursor onto the five targets on the screen using MAF by eye-gaze.

Table 1: The standard deviation of the mouse cursor movement within the each target.

MAF	Horizontal direction [pixel]	Vertical direction [pixel]
Without MAF	31,6	23,1
Using MAF	30,8	18,2

Table 2: The standard deviation of the mouse cursor movement within the each target.

The number of frames m for MAF	Horizontal direction [pixel]	Vertical direction [pixel]
10	2,9	3,2
20	2,1	2,1
30	2,5	3,1
40	2,6	3

The beginning of the eye blink is defined as the situation that the difference of vertical length of the iris region between consecutive two image frames is ten or more pixels. The end of the eye blink is defined as the situation that the vertical length of the iris region returns the level of the beginning of eye blink with a margin of ten pixels. The duration of eye blink is used to distinguish between voluntary and involuntary eye blink. The duration of 300 ms is used as the threshold based on the preliminary experiment. The value of the threshold is adjustable through a GUI window of the system for user convenience. Because the detection result is used as a trigger for holding the position of the mouse cursor during eye blink, erroneous movement of the mouse cursor during eye blink can be reduced. Moreover, the detection method allows us to apply voluntary eye blink to a mouse click function.

The system holds the position of the cursor during eye blink. Furthermore, for mouse click, the system holds the position of the cursor for 20 frames (660 ms) after the end of eye blink to prevent unsteady cursor movement in a transition state.

4.2 Experiments

The experiments for evaluating the detection method for eye blink and the mouse click function were done for the five subjects with normal eyesight. The moving average filter shown in Section 3.2 was used during the experiments. The experimental setup and the procedure are almost the same as in Section 3.2. In the experiments, each subject was requested to move mouse cursor to each target area of 60 x 60 pixels and to make a click through voluntary eye blink. This trial was repeated nine times with a randomly selected target among nine targets shown in Figure 8. The target points in the figure are located inside of the measurement area in Figure 5.

Table 3 shows a comparison of average distance between the target and the mouse cursor for the five subjects. Average values over the subjects show that the detection method is more effective in vertical direction. Table 4 shows average of the standard deviation of mouse cursor movement every one second while the experiments. Reduction of the deviation, i.e., fluctuation of the cursor point on the computer display is clearly seen in both directions.

Subjects A and B are skilled users, and the others are beginners. Table 3 suggests that skilled users are able to control the mouse cursor with a high accuracy through eye gaze using our interface system.

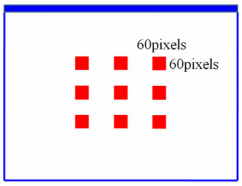

Figure 8: Nine target points on the display.

Table 3: The average distance between the target and the mouse cursor.

(a) Horizontal direction (x)

Subject	Without mouse cursor control during eye blink[pixel]	Using mouse cursor control during eye blink[pixel]
A	20.8	15.8
B	35.4	25.6
C	43.4	53.6
D	27.7	21.4
E	37.8	50.0
Average	33.0	33.3

(b)Vertical direction(y)

Subject	Without mouse cursor control during eye blink[pixel]	Using mouse cursor control during eye blink[pixel]
A	24.4	7.2
B	16.9	12.4
C	34.2	32.1
D	22.4	24.9
E	42.6	17.2
Average	28.1	18.8

Table 4: The standard deviation of the movement of the mouse cursor.

(a) Horizontal direction (x)

Subject	Without mouse cursor control during eye blink[pixel]	Using mouse cursor control during eye blink[pixel]
A	46.5	41.9
B	79.3	34.3
C	43.2	42.7
D	44.6	40.7
E	58.5	56.0
Average	54.4	43.1

(b) Vertical direction(y)

Subject	Without mouse cursor control during eye blink[pixel]	Using mouse cursor control during eye blink[pixel]
A	41.7	28.5
B	29.0	31.9
C	37.6	28.5
D	51.7	41.3
E	49.8	32.3
Average	42.0	32.5

5 CONCLUSIONS

In this paper, smooth cursor control using a moving average filter and detection of involuntary and voluntary eye blink were proposed and evaluated for developing an easy-to-use eye gaze interface system. The experimental results showed the usefulness of the proposed methods for quick and stable mouse cursor control.

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