Home Position Recognition Methods Using Polarizing Films for an Eye-gaze Interface System

Kohichi Ogata[1], Kensuke Sakamoto[2] and Shingo Niino[1]
[1]*Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan*
[2]*Faculty of Engineering, Kumamoto University, 2-39-1 Kurokami, Chuo-ku, Kumamoto 860-8555, Japan*

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Abstract: In eye-gaze interface systems, users' head movements during use result in detection errors. This problem causes inaccurate positioning of the mouse pointer on the display screen. A mechanism that allows the user to recognize the home position, which is an appropriate position for the head while using an eye-gaze interface system, can provide a useful solution to the problem because the user can then simply adjust his/her head position. The implementation of such a mechanism does not require special equipment, such as a position sensor to detect head movement and calculate compensation. We thus propose in this paper methods for recognizing the home position using polarizing films. Taking advantage of the characteristics of polarizing films, we propose two guidance methods to help an eye-gaze interface system user recognize whether or not his/her head is in the home position and adjust the position of the head if needed. The results of our experiments reveal that our proposed methods improve the usability of eye-gaze interface systems, and that one of our methods is more effective than the other. Therefore, our mechanism is useful in producing simple and low-cost interface systems.

1 INTRODUCTION

Users' head movements cause detection errors in eye-gaze interface systems. This leads to the undesirable positioning of the mouse pointer on the display screen. Therefore, it is necessary to somehow compensate for the troublesome movements in order to reduce errors.

A solution to the problem is to monitor head-related movements with multiple cameras (Talmi and Liu, 1999; Yoo and Chung, 2005; Noureddin et al., 2005). Such a method requires additional equipment to monitor movements and calculate the necessary compensation due to the movement based on the monitored deviation, which results in complex and costly systems. However, if a user can appropriately adjust the position of his/her head before pointing or clicking through an eye-gaze interface, the pointing error can be reduced. Therefore, taking into account the mechanism by which the user can recognize the deviation of the head from the home position, which is an appropriate position for the head while an eye-gaze interface is being used, is useful for creating simple, but effective and low-cost, interface systems. In order to realize such mechanisms, we propose methods for recognizing the head position using polarizing films (Ogata et al., 2012). Taking advantage of the characteristics of polarizing films, we propose two guidance methods to help recognize whether or not the user's head is in the home position and to accordingly adjust it. Experiments are conducted and a questionnaire is distributed in order to evaluate the usefulness of our proposed methods. The results contribute to providing users with a useful reference in order to recognize the home position while using eye-gaze interface systems. Because they render unnecessary the detection of the position of the head, our guidance methods enable the creation of simple and cheap eye-gaze interface systems.

2 EYE-GAZE INTERFACE SYSTEM

Our eye-gaze interface system (Yonezawa et al., 2008; Yonezawa et al., 2009; Yonezawa et al., 2010; Yonezawa, 2010) consists of a small visible light

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camera (Kyohritsu JPP-CM25F 1/3 inch CMOS 0.25 Mpixel) and a desktop computer (CPU: Intel Core i5-650 3.20 GHz, Memory: 2.92 GB, OS: Windows XP) with an image-capture board (Imagination PXC200). The system is capable of real-time processing with 320×240 pixels at 30 fps. The visible light camera is attached to the user's goggles to capture images of the right eye, and a computer display and a 20 W fluorescent table lamp are located in front of the user. We use a chin support in our system to provide a rest position and reduce the user's head movements. However, the development of a home position recognition method can render the chin support unnecessary for our system, and can hence expand its range of application.

2.1 Semi-dynamic Calibration (Ogata and Matsumoto, 2012)

In an eye-gaze-driven mouse-pointing system, the user perceives degradation in pointing accuracy through a discrepancy between the true eye-gaze and the position of the mouse pointer. Therefore, a semi-dynamic calibration (Ogata and Matsumoto, 2012) is installed in the system to update a mapping function between the center of the iris on the captured eye image and its corresponding calculated eye-gaze point on the display screen. The user can activate the semi-dynamic calibration mode anytime during use by blinking his/her eye for one second or longer.

3 PROPOSED METHODS USING POLARIZING FILMS

Figure 1 shows the schematic characteristics of a polarizing film. As is well known, the film can only be transmitted by light whose polarizing axis is parallel to the transmission axis of the polarizing film. If two films are used and their transmission axes are perpendicular to each other, the light can turn off. If we can apply these characteristics to a method that informs a user of his or her posture, it can serve as a low-cost but useful guidance tool. In this paper, we use paired polarizing films for the user to determine whether or not his/her head is at the home position.

Figure 2 shows the arrangement of the polarizing films (C-TASK CO., LTD, 0.2 mm thick, transmittance 38%, degree of polarization 95% or more). The equipment for the two proposed methods *Guide 1* and *Guide 2* is arranged around the computer display. The details of each method are as follows.

In Guide 1, paired polarizing films are placed below the display. Four polarizing films are arranged so that their transmission axes follow the directions shown in Figure 3(a). One set each of this mosaic-like design of film is attached to a white board and a transparent plastic plate, as shown in Figure 3(b). The white board and the plastic plate are arranged at a distance, as shown in Figure 3(c). If the user's head is at the home position, he/she sees white or gray polarizing films because of their parallel transmission axes. If the head is not at the home position, black zones appear on the polarizing films because the transmission axis of the polarizing film on the transparent plastic plate is perpendicular to that on the white board in these zones. An example of such situations is shown in Figure 3(d), where horizontal black zones appear because the head is out of position in the upper direction.

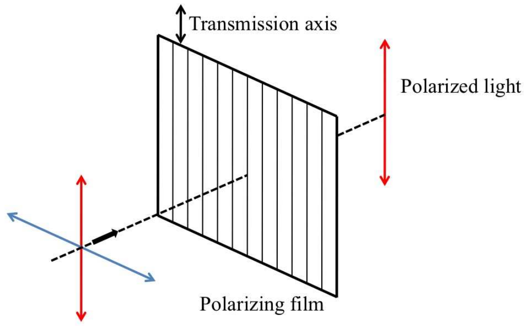


Figure 1: Schematic characteristics of a polarizing film.

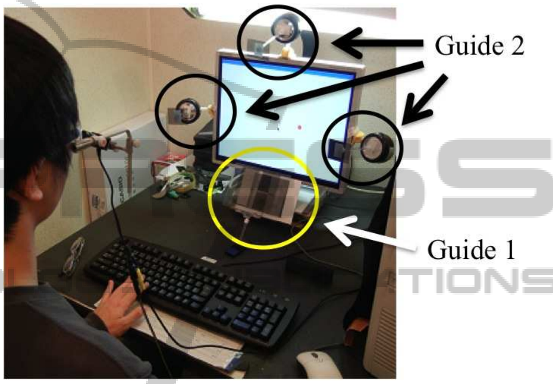
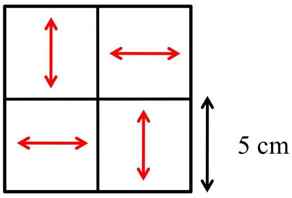
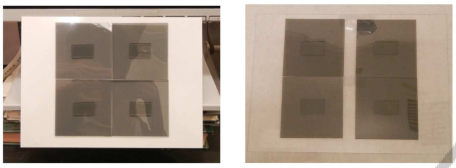


Figure 2: Arrangement of polarizing films.

In Guide 2, we use light-emitting diodes (LEDs) (Daiso Japan, D-011 LED LIGHT A no.5) and polarizing films. As shown in Figure 4(a), a plastic bar is attached to the front cover of the LED so that the axis of the bar is perpendicular to the face of the front cover. A polarizing film is attached to the tip of the bar so that the axis of the bar is perpendicular to the film. Another polarizing film is attached to the front of the user's goggles, as shown in Figure 4(b). Because the transmission axes of the polarizing films at-



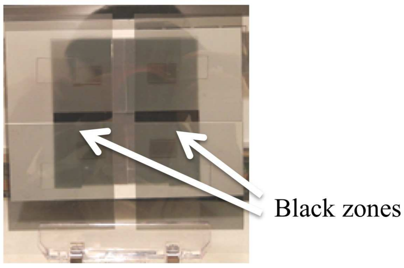
(a) Transmission axes of polarizing films.



White board Plastic plate

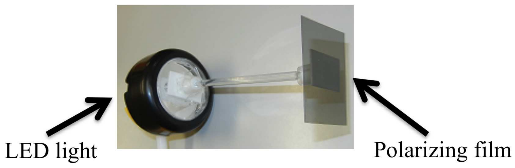
(b) A white board and a plastic plate. Each has a set of the four polarizing films shown in figure (a) on its surface.

(c) Arrangement of the white board and the plastic plate.

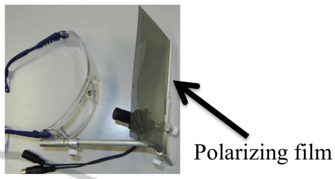


(d) Black zones when user’s head is out of position in the upper direction.

Figure 3: Arrangement of polarizing films in Guide 1.

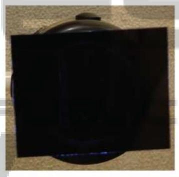


(a) Polarizing film attached to a plastic bar mounted on the front cover of an LED light.



(b) Polarizing film attached to the goggles.

Figure 4: Arrangement of polarizing films in Guide 2.



(a) View at the home position.

(b) View when a user bends his or her neck.

(c) View when user's head is shifted in left direction.

Figure 5: Examples of the LED lighting up.

tached to the LED and the goggles are perpendicular to each other, the light from the LED cannot reach the user’s eyes if his/her head is at the home position. As shown in Figure 2, three sets of polarizing film with LED are arranged on the frame of the display.

Figure 5 shows three examples of the appearance of the LED light. In case the head is at the home position, the light from the LED cannot reach the user’s eyes, as shown in (a). The other examples correspond to cases where the user bends his or her neck and the head consequently moves in the corresponding direction.

4 EXPERIMENTS

Experiments to test our proposed methods were conducted without the chin support. Five subjects with normal eyesight participated in the experiments. A 17-inch liquid-crystal display (LCD) with 1024 × 768 pixels was placed in front of the subject. The distance between the screen and the subject’s head varied from 60 to 80 cm. The variation arose because the chin support was not used, and thus each subject assumed a head position according to his/her comfort. Each subject was asked to gaze at one of 25 target points that randomly appeared one after another on the screen. The experiments consisted of three stages, involving the use of the eye-gaze interface (a) without the guides, (b) with the recognition method Guide 1, and (c) with the recognition method Guide 2. The subjects were randomly ordered in order to avoid the order effect in these stages. Semi-dynamic calibration was used if necessary.

5 EXPERIMENTAL RESULTS

Table 1 shows the pointing accuracy for all subjects in the use of the eye-gaze interface. Each value denotes the average accuracy over the 25 target points. The pointing accuracy for each target point was calculated from image data of 30 frames that correspond to 1 s. The accuracy varies with the users and the methods. The results suggest that the pointing accuracy of the eye-gaze system using our recognition methods is comparable to that without the methods. We think that because semi-dynamic calibration worked effectively to update the mapping function, the three conditions had no significant effect on improving the degree of accuracy.

Table 2 shows the time required for each trial. As shown in the table, the average time required for Guide 2 is 270.8 s, in contrast to 427.4 s without the guides. The number of times the semi-dynamic calibration was activated in each trial is also shown in Table 3. The shorter times needed suggest that the guide systems are useful in recognizing the position of the user's head and reducing the frequency of situations where the mouse pointer on the screen does not follow the user's gaze.

We performed usability evaluation at the end of the experiment for each subject. Table 4 shows the questionnaire items for evaluation. The subjects were asked questions related to ease of use, accuracy, and comfort of the system for each of the three conditions: *Without Guides*, *Guide 1*, and *Guide 2*. Items regarding the recognition of the home position and appropriate adjustment of the head position were added to the questionnaires for Guide 1 and Guide 2. Because a polarizing film is attached to the front of the goggles, as shown in Figure 4(b), an item regarding visibility was added to the questionnaire for Guide 2. The final item was the subjects' overall impression of the usefulness of the guides.

Table 5 shows the results of the questionnaire. Items (1) to (14) were evaluated on a grading scale ranging from 1 (poor) to 5 (good). Item (15) was evaluated according to the number of subjects who preferred the method. As indicated in item (15), all subjects preferred the system with guides. Among the three conditions, Guides 1 and 2 recorded higher scores on the three common items regarding ease of use, accuracy, and comfort. A comparison of the scores for items (7), (8), (12), and (13) shows that Guide 2 is superior to Guide 1 in terms of recognizing the home position and appropriately adjusting the head position. In a comment form provided in the questionnaire, a subject pointed out that Guide 2 was more suitable for shortsighted people than Guide 1. Another subject pointed out that the polarizing film attached to the goggles helped improve visibility. This suggests that the film eliminated part of the light from the display and made it easier for the subject to see.

Table 1: Results of pointing accuracy.

	Accuracy [pixels]		
Subjects	Without Guides	Guide 1	Guide 2
Subject 1	34.6	44.5	44.1
Subject 2	57.2	65.3	56.3
Subject 3	47.8	36.5	26.1
Subject 4	61.3	84.7	80.7
Subject 5	75.5	53.6	55.3
Average	55.3	56.9	52.5

Table 2: Time required in each trial.

	Time [s]		
Subjects	Without Guides	Guide 1	Guide 2
Subject 1	374.9	248.6	189.4
Subject 2	409.1	570.3	307.9
Subject 3	674.0	161.1	258.3
Subject 4	312.1	266.1	252.1
Subject 5	366.9	226.3	346.3
Average	427.4	294.5	270.8

Table 3: The number of uses of semi-dynamic calibration in each trial.

	Number [times]		
Subjects	Without Guides	Guide 1	Guide 2
Subject 1	11	5	3
Subject 2	5	7	6
Subject 3	21	1	4
Subject 4	8	7	5
Subject 5	6	3	3
Average	10.2	4.6	4.2

6 CONCLUSIONS

In this paper, we proposed two methods for recognizing the user's head position using polarizing films

Table 4: Items in the questionnaire regarding ease of use.

	Without Guides
(1)	Easy to move the mouse pointer to a target.
(2)	Accuracy improved after semi-dynamic calibration.
(3)	Did not feel tired after pointing 25 targets.
	Guide 1
(4)	Easy to move the mouse pointer to a target.
(5)	Accuracy improved after semi-dynamic calibration.
(6)	Did not feel tired after pointing 25 targets.
(7)	Easy to recognize the home position through the guide.
(8)	Easy to move the head to the home position.
	Guide 2
(9)	Easy to move the mouse pointer to a target.
(10)	Accuracy improved after semi-dynamic calibration.
(11)	Did not feel tired after pointing 25 targets.
(12)	Easy to recognize the home position through the guide.
(13)	Easy to move the head to the home position.
(14)	The polarizing film did not interfere with visibility.
	Overall impression
(15)	Which is easier, with or without the guides?

Table 5: Results of the questionnaire with grading scale ranging from 1 (poor) to 5 (good). Item (15) indicates the number of the subjects who chose between using the system with and without the guides.

	Without Guides
(1)	2.6
(2)	3.4
(3)	2.8
	Guide 1
(4)	3.4
(5)	4.4
(6)	3.0
(7)	3.2
(8)	3.0
	Guide 2
(9)	3.6
(10)	4.4
(11)	3.4
(12)	4.6
(13)	4.2
(14)	3.6
	Overall impression
(15)	with: 5, without: 0

in an eye-gaze interface system. Our experiments showed that the pointing accuracy of our proposed methods is comparable to that of the conventional method because semi-dynamic calibration works effectively to update the mapping function between the center of the iris in the captured eye image and the calculated eye-gaze point on the display screen. However, the guides are useful in reducing the frequency of activation of the semi-dynamic calibration method because the user can easily recognize the home position through the guides. Therefore, our proposed methods help reduce the time required to point accurately on the display in eye-gaze interface systems. The results from our experiments and the questionnaire revealed that the proposed methods improve the usability of our system.

Although the user in our method needs to move his/her head to the home position before pointing or clicking in an eye-gaze interface, our proposed methods are a reasonable solution as shown in the experiments. They permit free head movement except when pointing or clicking. Because our eye-gaze interface system captures eye images through a camera attached to goggles, additional equipment will be required if we try to introduce a compensation technique, such as face detection-based approaches. Our methods proposed here is effective and avoids overcomplicating the system. Moreover, because it is not necessary to modify the internal mechanism of the eye-gaze system in order to implement our methods, they serve as a versatile assistance tool. Further improvement is needed to develop more sophisticated guidance tools.

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