3D Interaction Technique on Stereo Display System

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Abstract

There are several researches on 2D gaze tracking techniques to the 2D screen for the Human-Computer Interaction. However, the researches for the gaze-based interaction to the stereo images or 3D contents are not reported. This paper presents a gaze-based 3D interaction technique on autostereoscopic display system.

1. Introduction

Many researches on gaze estimation technique for inferring a fixation point on the 2D screen have been reported [1-4]. One of the typical methods is PCCR (Pupil Center & Corneal Reflection)-based approach [1]. The model-based approach is also reported in which gaze direction is estimated from monocular or stereo camera while using 3D face model [2-3]. The gaze direction estimation technique is proposed while using stereo vision technique for the estimation of 3D eye position and gaze direction [4]. However, all of these techniques address the estimation of gaze fixation point on the 2D screen.

In this paper, we address 3D gaze direction and depth estimation technique and its application to the gaze-based interaction in the stereo display. There are several researches on eye vergence and movement, although their main objectives are not for the gaze computer interaction. Recently, a research on 3D gaze estimation is reported while using anaglyph-based HMD and commercial binocular eye tracking system in the context of the investigation of human visual system in 3D scene.

The 2D gaze to a fixation point on the 2D screen can be estimated with single eye. However, the 3D gaze can be estimated with both eyes, because 3D gaze needs not only gaze direction but also gaze depth. Until now, the most researches focus on only single-eye based gaze direction estimation for the application to the 2D display. In this paper, we address the estimation of 3D gaze using the gaze direction and the gaze depth from both eyes. The estimation of gaze direction and gaze depth from both eyes is a new important research topic for 3D gaze interaction. The contribution of this paper can be summarized as follows. This paper presents an algorithm for estimating the 3D gaze, which only needs one monocular camera and IR LEDs. The proposed algorithm is implemented and applied to the parallax barrier type stereo display while using 3D contents. Moreover, our technique is applied to the 3D gaze-based interaction to object in 3D virtual space and evaluated.

2. Algorithm

The principal algorithm for 3D gaze estimation is shown in Fig. 1. There are two steps for 3D gaze estimation, i.e., first estimate the gaze direction using our developed triangle method and the gaze direction using our concept of PCD (Pupil Center Distance).

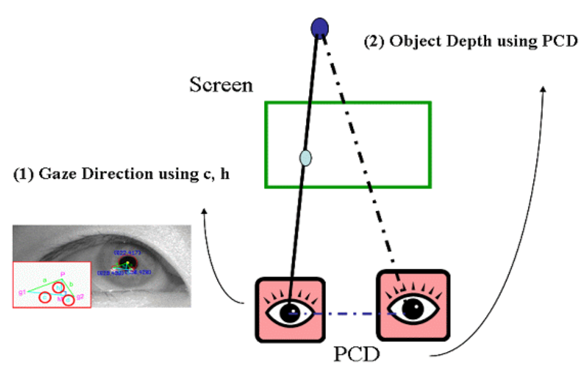


Fig. 1. Overview of 3D Gaze Estimation Algorithm

Fig. 2 shows the concept for finding 3D gaze target point or region from the gaze direction and the gaze depth. As shown in Fig. 2, we first estimate the gaze direction using our triangle method and then estimate gaze depth plane using PCD value and finally estimate the target point or region by intersecting the gaze direction and gaze depth plane.

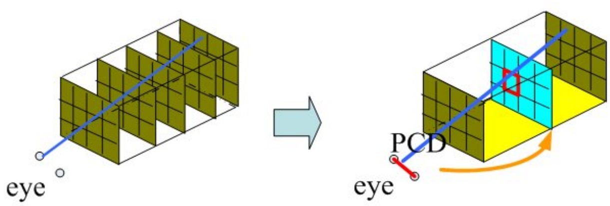


Fig. 2. Find 3D Gaze Target from the Gaze Direction and the Gaze Depth

3. 3D Stereo Image Interaction

We use two IR LEDs and one dragonfly camera with infrared filter (LP830-27). We also use chin-rest for fixing head. For 3D display device we use parallax barrier type stereo display. (Model No PAVONINE PA3D-17EXN). Fig. 3 shows our system for 3D gaze estimation with parallax barrier stereo display.

Fig. 3. 3D Gaze Estimation System

Before the using system, each user performs the personal calibration. Our calibration procedure can be divided into 3 steps. The user stares at 3 point (left-top, right-bottom, and center) in the nearest depth and the farthest depth. We can find a gaze direction range from relations between pupil and glints at each depth. And we can also find a PCD range at each depth. We can know a c, h, PCD value at each depth because we assumed linear relation. Fig. 4 shows the procedure of personal calibration.

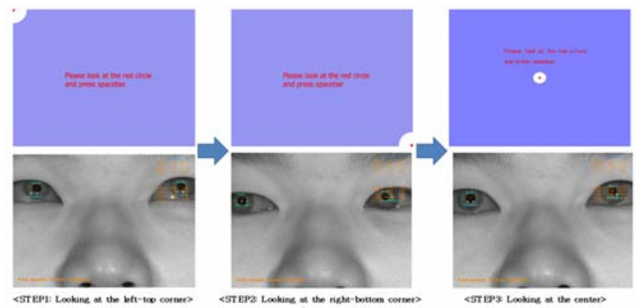
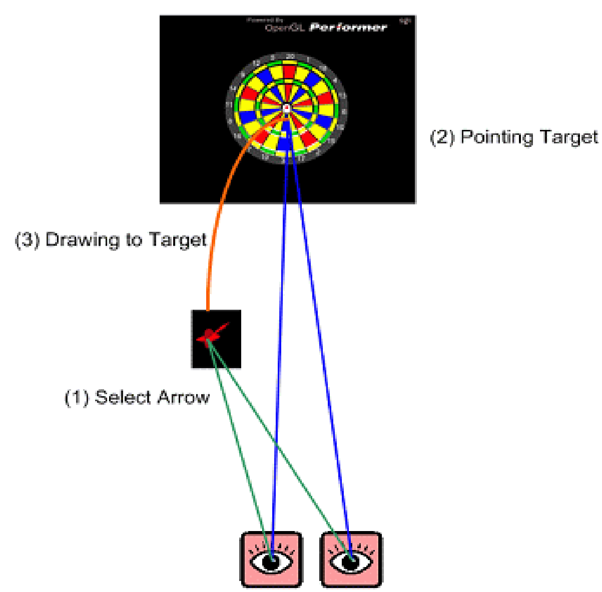


Fig. 4. Personal Calibration

We apply our 3D gaze estimation algorithm to the gaze-based 3D interaction to stereo display. We developed 3D contents with OpenGL Performer while the contents are displayed on stereo display. The 3D contents are composed with dart and arrow, in which dart is located far and arrow is located in near in 3D space. The distance is 840mm between user and display.

Fig. 5 shows our demo scenario for gaze-based 3d interaction. There are three steps, first select arrow with gaze, second pointing target point on dart with gaze, then the arrow will be drawn to the target point on dart. And it shows a screenshot of the demonstration of 3D gaze interaction using our 3D dart-arrow stereo contents.



(a)

(b)

Fig. 5. Scenario of 3D Gaze Interaction to Stereo Contents (a) and Demo System (b)

Table 1 shows the measured experimental data of c, h, and PCD values from two subjects for our 3D gaze-interaction demo. In the table 1, the value of Gaze X and Y are measured c and h values at the given depth, respectively.

TABLE 1. Experimental Data of Gaze Direction and Gaze Depth

	Subject 1	Subject 2
Gaze X (840mm)	12 ~ 41.4	4.6 ~ 33.2
Gaze X (2600mm)	17 ~ 24.5	12 ~ 24.2
Gaze Y (840mm)	6.7 ~ 25.9	7.3 ~ 24.9
Gaze Y (2600mm)	10 ~ 15.2	14 ~ 20.7
PCD (840mm)	592 ~ 593	578 ~ 579
PCD (2600mm)	600 ~ 601	586 ~ 587

(a) Personal Calibration Data

Index	Depth (mm)	Gaze X	Gaze Y	PCD(pixel)
1	630	9~49.79	5~31.32	588~599
2	840	12~41.4	6.7~25.9	592~593
3	1270	14.3~33	8.3~20.6	596~597
4	2600	17~24.5	10~15.2	600~601

(b) Subject 1 : Estimation Data from (a)

Index	Depth (mm)	Gaze X	Gaze Y	PCD(pixel)
1	630	1~37.7	5.67~27	574~575
2	840	4.6~33.2	7.3~24.9	578~579
3	1270	8.3~28.7	10.7~19	582~58.
4	2600	12~24.2	14~20.7	586~587

(c) Subject 2: Estimation Data from (a)

4. Evaluation

We evaluate the accuracy of the system about Gaze X(c), Gaze Y(h) and PCD. The Gaze X, Gaze Y mean x-coordinate, y-coordinate value of gaze direction, respectively. The accuracy of PCD corresponds to that of the estimated gaze depth. The 3D space is divided by 9 x 3 volumes for evaluation as shown in Fig. 6.

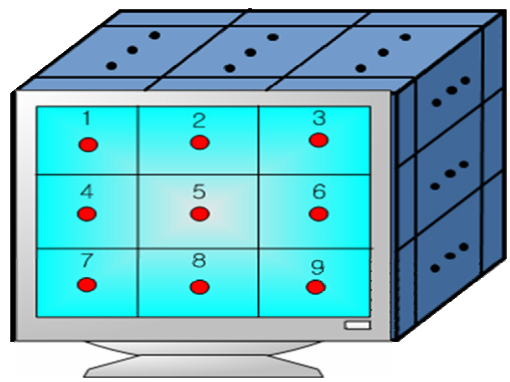


Fig. 6. Fixed points of experimental object

From the personal calibration data shown in table 1, the range of Gaze X(c), Gaze Y(h) and PCD value at three depths are estimated. Then, the values of Gaze X(c), Gaze Y(h) and PCD for each volume shown in Fig. 4 are estimated

For example, we can estimate the ranges of Gaze X(c) at nine volumes @ 630 mm as follows: the range of Gaze X(c) of 1, 4, 7 volume is 9~22.6 ; the range of Gaze X(c) of 2, 5, 8 volume is 22.6~36.2 ; the range of Gaze X(c) of 3, 6, 9 volume is 36.2~49.79).

Then, we look at the nine fixed points at each depth. The fixed point is located in a center of the front surface of each volume. When we look at the nine fixed points, we evaluate the accuracy whether the each value exists in the obtained value range. We look at the 3 times per each volume. The results are shown in Table 2. The calibration data and the accuracy evaluation result are shown in the left and the right part, respectively.

TABLE 2. Accuracy Evaluation

Subject 1

Depth (mm)	Range of each value (calibration)		
	Gaze X(c)	Gaze Y(h)	PCD
630	9~49.79	5~31.32	588~589
840	12~41.4	6.7~25.9	592~593
1270	14.3~33	8.3~20.6	596~597

Depth (mm)	Data Accuracy (real object)		
	Gaze X(c)	Gaze Y(h)	PCD
630	27/27 (100%)	25/27 (92.5%)	25/27 (92.5%)
840	27/27 (100%)	26/27 (96.2%)	27/27 (100%)
1270	25/27 (92.5%)	27/27 (100%)	27/27 (100%)

Subject 2

Depth (mm)	Range of each value (calibration)		
	Gaze X(c)	Gaze Y(h)	PCD
630	1~37.7	5.67~27	574~575
840	4.6~33.2	7.3~24.9	578~579
1270	8.3~28.7	10.7~19	582~583

Depth (mm)	Data Accuracy (real object)		
	Gaze X(c)	Gaze Y(h)	PCD
630	27/27 (100%)	27/27 (100%)	26/27 (96.2%)
840	27/27 (100%)	27/27 (100%)	27/27 (100%)
1270	25/27 (92.5%)	27/27 (100%)	27/27 (100%)

We also evaluate the final 3D gaze using 3D gaze direction and gaze depth in our 3D dart-arrow demo system. We are divided by 12(region) X 4(depth) volumes on the screen for evaluation. We display arrow at the random point and evaluate whether our 3D gaze can select the displayed arrow. Fig. 7 shows 3D contents for the proposed algorithm accuracy evaluation.

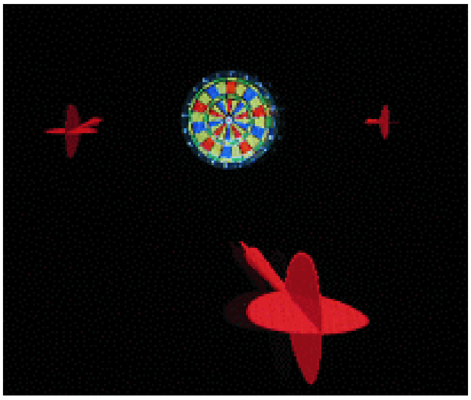


Fig. 7. 3D contents for the proposed algorithm accuracy evaluation

We evaluate our known c, h, and PCD value with real-measure data in our implemented 3D gaze demo system. The results are shown in Table 3. It should be mentioned that we evaluate the accuracy under the condition our system can get the correct 3D gaze information within 1 second. As shown in table 3, we have at least 93 % accuracy within 1 second.

TABLE 3. 3D Gaze Estimation Accuracy

Subject	Accuracy
Subject 1	97% (29/30)
Subject 2	93%(28/30)
Subject 3	93% (28/30)

5. Summary

This paper addresses the gaze-based 3D interaction techniques to 3D contents which are displayed on parallax barrier stereo display. Our system's advantage is only using a camera and two IR LEDs so that it doesn't need resources. We find not only gaze direction but also gaze depth to add PCD concept. This paper presents 3D gaze estimation algorithm. We also show the 3D gaze interaction technique to 3D contents on the stereo display. In Accuracy evaluation, our system has accuracy more than 92.5%. Our current research result shows that the proposed 3D gaze estimation technique can be used as new interaction schemes for stereo display, 3D game, and virtual reality and so on.

6. References

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