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# 3차원 시선기반 입체영상 인터랙션 기법

## 3D Gaze-based Stereo Image Interaction Technique

Jeongseok Ki, Kyeong-Won Jeon, Sangwoo Jo, Yong-Moo Kwon, Sung-Kyu Kim  
Korea Institute of Science & Technology

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**Abstract** – There are several researches on 2D gaze tracking techniques for the 2D screen for the Human-Computer Interaction. However, the researches for the gaze-based interaction to the stereo images or contents are not reported. The 3D display techniques are emerging now for the reality service. Moreover, the 3D interaction techniques are much more needed in the 3D contents service environments. This paper addresses gaze-based 3D interaction techniques on stereo display, such as parallax barrier or lenticular stereo display. This paper presents our researches on 3D gaze estimation and gaze-based interaction to stereo display.

**keyword** : 3D Gaze, Eye Vergence, 3D Interaction, Stereo Display

### 1. Introduction

With the ever increasing role of computers in society for future ubiquitous environment, human-computer interaction (HCI) has become an increasingly important part of our daily lives to connect between man and machine seamlessly. It is widely believed that as the computing, communication, and display technologies progress even further, the existing HCI techniques may become a bottle-neck in the effective utilization of the available information flow. For example, the most popular mode of HCI still relies on the keyboard and mouse. These devices have grown to be familiar but tend to restrict the information and command flow between the user and the computer system [1]. More natural ways of dealing with computer could be via talking, gesturing, hearing, and seeing.

There have been reported several researches on gaze tracking techniques using monocular camera [2] or stereo camera [3-4]. The most popular used gaze estimation techniques are based on PCCR (Pupil Center & Cornea

Reflection). These techniques are for gaze tracking for 2D screen or images. The researches on eye vergence also have been reported [5-6]. In [6], the monitoring system of eye vergence is implemented with HMD (Head Mounted Display). But these techniques are 2D gaze.

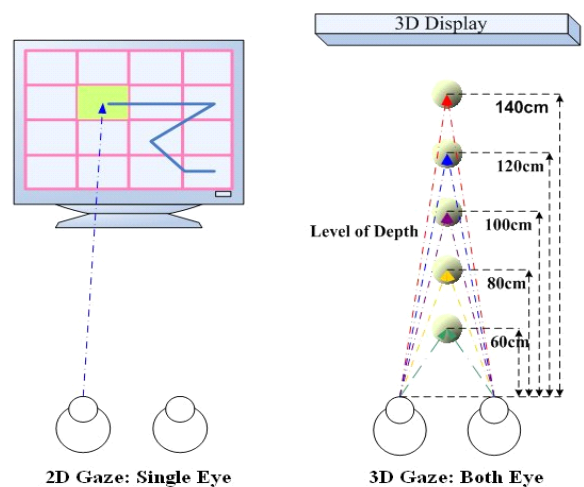


Fig. 1. The concept of 2D and 3D gaze

In this paper, we address 3D gaze estimation and application to gaze-based interaction to stereo display. To the best of our knowledge, our paper first addresses the 3D gaze interaction techniques with stereo images. Fig. 1 shows the difference between 2D gaze and 3D gaze concept. As shown in Fig. 1, the 2D gaze can be estimated with single eye. However, the estimation of 3D gaze needs gaze from both eyes. Until now, the most researches are focused on only single-eye-based gaze direction for the application to 2D space. The reason is explained more detail in Fig. 2.

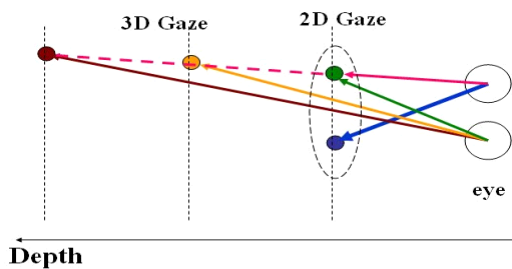


Fig 2. Gaze Direction and Gaze Depth

From single eye, we find a gaze direction. But we can't find a gaze depth. Because there are many gaze depth about same direction in Fig.2. Thus we find a gaze depth from the both eyes.

In this paper we suppose a gaze tracking technique from both eyes using one camera and two IR LEDs. We first propose our algorithm for 3D gaze estimation that is composed of gaze direction estimation and gaze depth estimation. Second, we present the implementation of our algorithm. Then the evaluation of our system is provided. The application of our algorithm to stereo contents is described.

## 2. 3D Gaze Estimation Algorithm

Our proposed algorithm is very simple. We find a gaze direction using a pupil and two glints in input eye image. And we find a gaze depth using a pupil center distance(PCD).

### 2.1 Gaze Direction Estimation

We use the relationship between pupil center and gaze point on the screen. It can be understood easily that the pupil center is moved according to the gaze point on the

target point of the screen. Here we use Purkinje image for eye, which includes the pupil and glint from IR LED. Using image processing, the pupil center (PC) and glint center (GC) are extracted. To estimate the gaze point on the screen, we used distance values among three feature points which are pupil center  $P$  and two glints' centers,  $g1, g2$ , shown in Fig. 3.

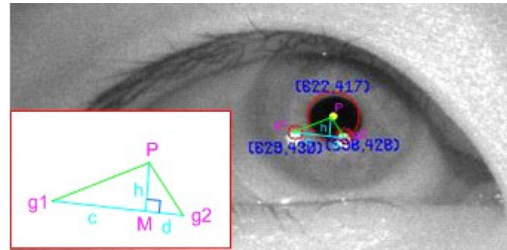


Fig 3 Feature Relations of Gaze Tracking Algorithm

Assumed that the linear relations of distance values and the gaze point,  $h$  is used to map the gaze point of the screen  $y$ -axis and  $c$  is used to map the gaze point of the screen  $x$ -axis. By the way, because field of view is different about each user, We perform the personal calibration. With initial values of user' s individual factor in the personal calibration, the system calculates the gaze point on the screen using these two values. Fig. 4 shows the concept gaze direction estimation and screen mapping. As shown in Fig. 4, the value of  $c$  and  $h$  correspond to  $x_c$  and  $y_h$  on the screen, respectively.

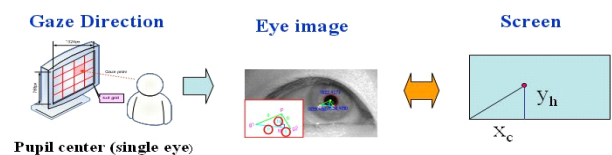


Fig 4. Gaze Direction Estimation and Screen Mapping

We need more than two points to find a direction in 3D space. Thus we use another point  $c, h$ . In Fig.5, it is top view that represent concept of gaze direction estimation to find a direction in 3D space. In Fig.5,  $c, h$  value is represented at the monitor. So it is same the  $c(3.5)$  value at 840mm and the  $c$  value at 2600mm But mapping point is a different because  $c$  value range is a different at each depth. Thus if the screen size is 0~100 and  $c$  value range is 0~10 at 840mm,  $c$  value(3.5) is 30. If  $c$  value range is 2.5~7.5 at 2600mm,  $c$  value(3.5) is 20.

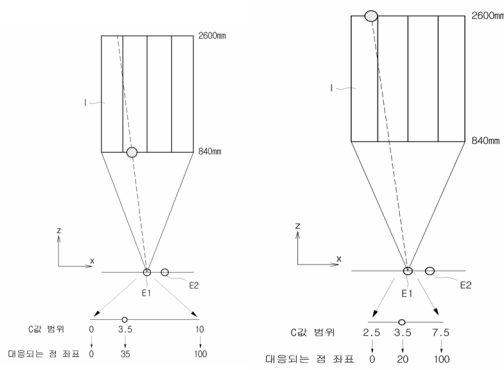


Fig 5. 3D Gaze Direction Estimation

## 2.2 Gaze Depth Estimation

We use the concept of Pupil Center Distance (PCD) between both eye pupil centers for finding the depth. The idea is that the PCD changes according to depth. It should be noted that the PCD increases (decreases) when object appears far (near) from eye. Fig. 6 shows the relationship between the gaze depth and PCD.

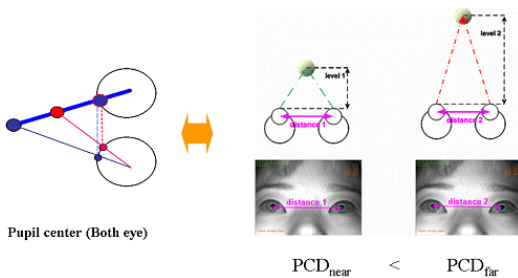
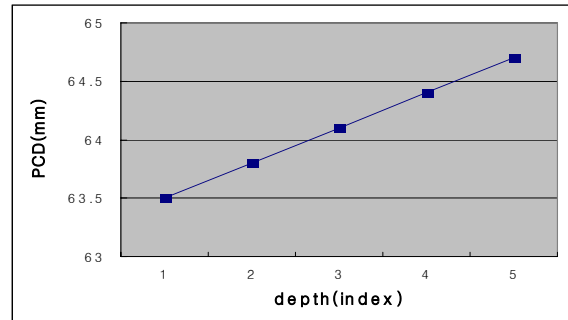


Fig 6 Gaze Depth and PCD(Pupil Center Distance)

Fig. 7 shows the result to simulation. In result the PCD increases (decreases) when object appears far (near) from eye. We divided a depth according to linear PCD value.

And depth and PCD is different about each user, we perform the personal calibration.



index	depth(mm)
1	500
2	630
3	840
4	1270
5	2600

Fig 7. Relationship between depth and PCD

## 2.3 Gaze Depth Estimation Algorithm

The principal algorithm for 3D gaze estimation is shown in Fig. 8. There are two steps for 3D gaze estimation, i.e., first estimate the gaze direction using triangle method described in Sec 2.1 and gaze direction using PCD described in Sec. 2.2.

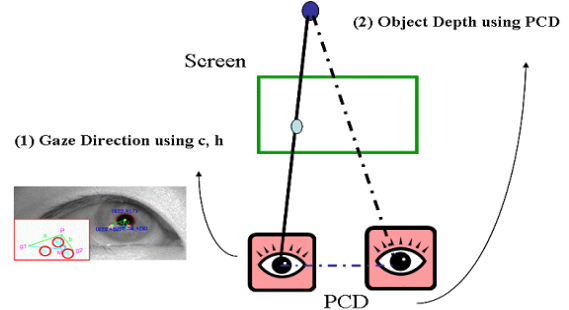


Fig 8. Overview of 3D Gaze Estimation Algorithm

Fig. 9 shows the concept for finding 3D gaze target area from Gaze Direction and Gaze Depth. As shown in Fig. 9, we first estimate the gaze direction using  $c$  and  $h$  value and then estimate gaze depth plane using PCD value and finally get the target region while intersection of gaze direction and gaze depth plan.

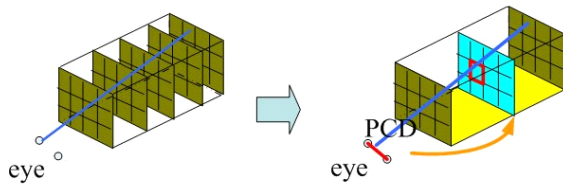


Fig 9. Estimation of 3D Gaze Target area from Gaze Direction and Gaze Depth

### 3. 3D Stereo Image Interaction

#### 3.1 System Implementation

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. 10 shows our system for 3D gaze estimation with parallax barrier stereo display.



Fig 10. 3D Gaze Estimation System

#### 3.2 3D Stereo Image Interaction

Before the using system, each user perform the personal calibration. our calibration procedure can be divided into 3 steps. The user stare at 3 point ( left-top, right-bottom, 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 11. shows the procedure of personal calibration.

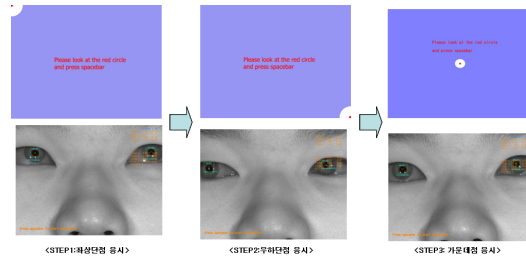


Fig 11. Personal Calibration

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. 12 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.

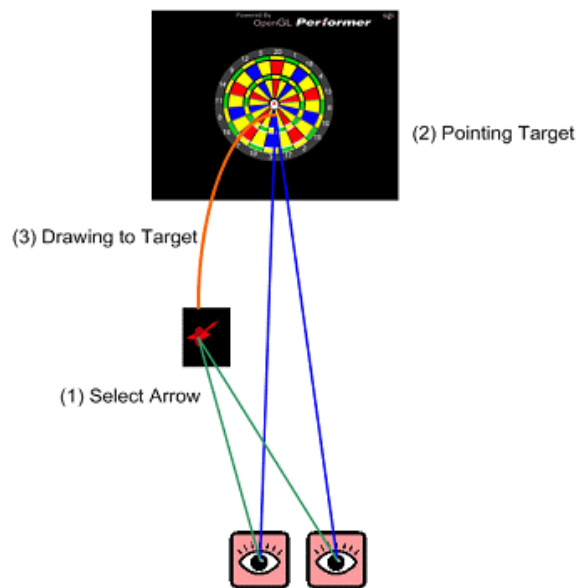


Fig 12. Scenario of 3D Gaze Interaction to Stereo Contents

### 4. Evaluation

#### 4.1 Gaze Direction

The gaze point accuracy of the proposed system is simply decided by the experiment of looking at sixteen fixed points on the screen for evaluation.

Four subjects were asked to stare at sixteen points, three times in order. Fig. 13 shows the average error for each target of four users, while evaluating x and y direction. There are no resultant error larger than 18pixel at the resolution 1024 X 768. Pixel value replace with degree value. degree equation is  $\theta = \left(\arctan\frac{e}{600}\right)$ .

There are no resultant error larger than 0.60 degree and the result is almost uniformly distributed around 0.40 ~ 0.50 degree

Sheng Wen Shih's system use a vector that find from cornea center and pupil center using a stereo camera[4]. This system's error is about 1 degree. Our system is better than Sheng Wen Shih's system.

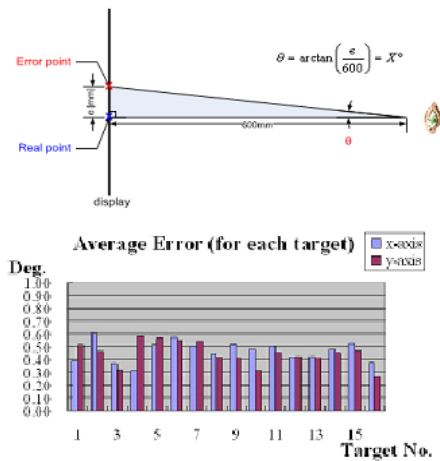


Fig 13. Accuracy evaluation of our gaze direction estimation

#### 4.2 3D Gaze Direction and Depth

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 12regions on the screen for evaluation. Even though screen region is divided by 12regions in 3D gaze estimation, divided by 16regions in 2D gaze estimation, that's no meaning. We display arrow at the random point and evaluate whether our 3D gaze can select the displayed arrow. Fig 15. shows 3D contents for the proposed algorithm accuracy evaluation.

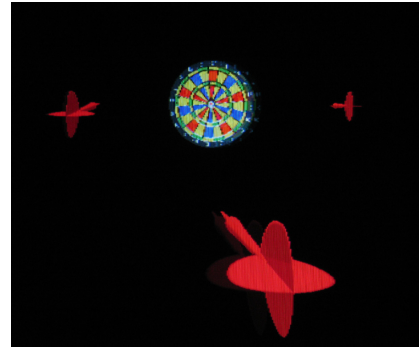


Fig 15. 3D contents for the proposed algorithm accuracy evaluation

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 1. 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, we have at least 93 % accuracy within 1 second.

Table 1. Accuracy Evaluation of 3D Gaze Estimation

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

#### 5. Conclusion

↓ 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 LED 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, gaze direction error is 9~18pixel and gaze depth error is 94.5%. 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.

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