Representing Gaze Direction in Video Communication Using Eye-Shaped Display

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ABSTRACT
A long-standing challenge of video-mediated communication systems is to correctly represent a remote participant's gaze direction in local environments. To address this problem, we developed a video communication system using an "eye-shaped display." This display is made of an artificial ulexite (TV rock) that is cut into a hemispherical shape, enabling the light from the bottom surface to be projected onto the curved surface. By displaying a simulated iris onto the eye-shaped display, we theorize that our system can represent the gaze direction as accurately as a real human eye.

Author Keywords
Telecommunication; perception of gaze direction;

ACM Classification Keywords
H.4.3 Communications Applications: Computer conferencing, teleconferencing, and videoconferencing; H.5.3. Information interfaces and presentation (e.g., HCI): Group and Organization Interfaces

INTRODUCTION
Gaze is one of the most important factors in human communication [7, 9, 12]. For example, eye contact plays an important role in turn taking in face-to-face communication. In the case of video communication, however, the gaze direction of remote participants cannot be represented properly on a display, which undermines certain collaborative tasks between the participants [8]. This effect is called the Mona Lisa effect [4], which is a phenomenon that causes the eyes in a portrait to appear to follow observers as they move.

To address this problem, telepresence robots that use LCDs as face displays have been proposed [1, 11]. For example, MeBot [1] has a three-degrees of freedom (3DOF) movable display (head) and two 3DOF arms. The system detects the remote participant's face orientation and synchronizes MeBot's head orientation. The researchers expected these face displays to have the ability to provide gaze awareness; however, Kawaguchi *et al.* determined that even with a rotatable display, it is not easy to represent remote participant's gaze direction properly [10].

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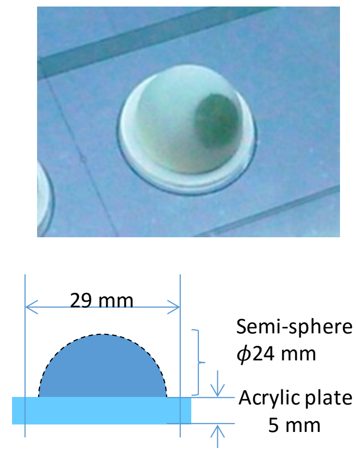

Figure 1. Eye-shaped display.

Some researchers have developed a system that utilizes a 3D face-shaped screen with a 3D motion platform [3, 13]. Theoretically, such screens are effective in reducing the Mona Lisa effect; however, a limitation with the system is the lack of general versatility because each screen needs to be made such that it matches the remote participant's face. A simpler approach is attaching a motor-operated eye [14] to a video conferencing system. However, adding extra actuators inevitably decreases the simplicity of the system.

In our study, we propose an eye-shaped display that imitates the shape of a human eye ball and adds to a video communication system as an auxiliary. Brockmeyer et al. proposed to create the eye-shaped display using 3D printed light pipes [2]. We created our eye-shaped display from a ulexite (TV rock) (Figure 1). We theorize that this display may contribute to increasing gaze direction perception of the remote participant during video communication. For the remainder of this paper, we describe the development of our eye-shaped display and outline possible use cases.

EYE-SHAPED DISPLAY
Figure 1 shows our eye-shaped display. We made this display by cutting a commercially available artificial ulexite

into a hemispherical shape. Ulexite has a characteristic that it can project an image from the bottom surface to the opposite surface. As a result, the image appears to float on the spherical surface. For example, drawing a moving eye on a flat LCD and placing the eye-shaped display on the LCD, it looks as if the eye ball is rotating.

Given that the average diameters of a human eye ball and an iris are 24 mm and 12 mm, respectively [5], our eye-shaped display and its iris were made to match these sizes. The shape of the iris that is drawn on the LCD is calculated so that it becomes a true circle when it appears on the surface of the eye-shaped display. Figure 2 shows the schematic diagram for calculating the contour of the iris on the LCD. Let us assume that the initial position of the iris is at the zenith of the sphere. In this case, a point on the contour of the iris $\overrightarrow{p_i}$ can be easily calculated. When the eye ball is rotated, a rotated vector is calculated as $\overrightarrow{p_i}' = \overrightarrow{p_i}\, R(\theta_y)\, R(\theta_z)$, where $R(\theta_y)$ and $R(\theta_z)$ are rotation matrices around y axis and z axis, respectively. By taking only x and y coordinates of $\overrightarrow{p_i}'$, the iris for rotated eye ball can be drawn on the LCD (*x*-*y* plane).

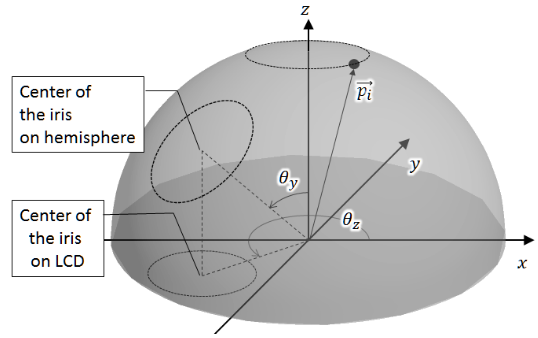

Figure 2. Calculating the collected contour of the iris.

APPLICATIONS

We are implementing a video-conference system using the eye-shaped display (Figure 3). The gaze direction of the eye-shaped display is calculated by tracking a remote participant's gaze direction using an eye tracker. Theoretically, this method helps a local participant perceive the remote participant's gaze direction accurately.

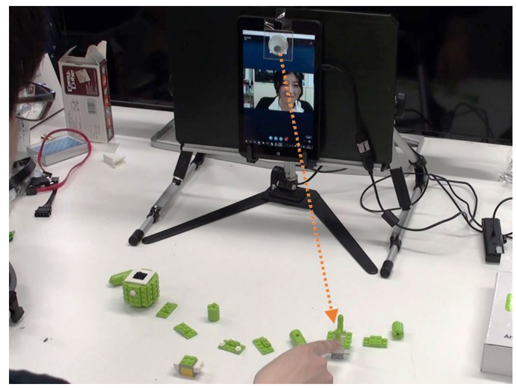

Figure 3. Video conference system using eye-shaped display.

We are also planning to apply the eye-shaped display to a remote instruction system, which uses a hand-held terminal as a video see-through device [6]. When a remote instructor wants to refer to an object that lies outside the view of the device, the eye-shaped display indicates the direction toward the object. We are expecting that the worker may involuntarily react to such an eye movement and move the device toward the gaze direction.

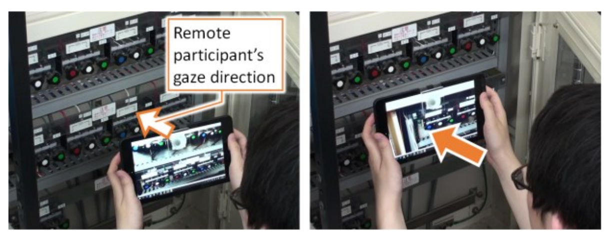

Figure 4. An example of a remote instruction system.

CONCLUSION

This paper proposes to use an eye-shaped display for a video communication system that enables the local participant to accurately estimate the remote participant's gaze direction. Since this technology does not require additional electricity, we believe it is especially useful for tablet terminals and smartphones.

Our future work includes assessing the accuracy of perceiving a remote participant gaze direction and also examining the effect of adding an eyelid. Additionally, we plan to investigate the effect of our eye-shaped display on actual video communications.

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