34.2: Multiple-Viewing-Angle Projection-Display Technique for Videoconferencing

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Abstract

We have developed a technique that changes the image seen on a screen depending on the viewing angle. A new display apparatus for video conferences based on this technique projects multiple images of participants taken from different angles onto a directional screen consisting of a directional diffusion plate and lens. This display apparatus provides us with the natural feeling and comfort of directly talking in the same room. This report describes the directional screen, multidirectional projecting, and multidirectional picture shooting, which are important elements of this technique.

1. Introduction

Future telecommunications service should include interactive video conference systems that give one the impression of talking face-to-face in the same room. Current TV conference systems consist of a display, video camera, and communication control equipment. In such a system, when we move and view the display from a different angle, we still see exactly the same image. But, in an actual conference, participants talking face-to-face make eye contact with each other, and a participant on the other side who is making eye contact with someone else on this side is seen at an angle. Therefore, current TV conference systems are different from real life, so they reduce the naturalness of the conversation. Thus, we would like to have an image that changes according to the viewing angle, so we can make eye contact with the other participants as if talking face-to-face.

The eye contact method[1] already reported as a technique for controlling the visual field suffers from poor display brightness and a narrow viewing angle. We solved these problems by using a directional screen consisting of a directional diffusion plate and lens. In particular, our technique is based on using a directional diffusion plate having a dispersion angle that is relatively narrow for the luminance characteristics of the light transmitted through the plate. We tried to separate multiple images projected on the directional screen by matching the projection angle to the viewing angle and to achieve eye contact by projecting an image matching the viewing angle to the shooting angle. As a result, we have developed a novel display apparatus that provides one with a natural feeling of talking directly in the same room even though it is actually a teleconference.

2. Structure of Directional Screen and Oblique Projection Image

2.1 Directional Screen

We investigated plates of various structures to obtain a directional diffusion plate having a relatively narrow dispersion angle. We found that desirable characteristics were obtained with a plate consisting of numerous small partial spheres laid on the surface of a transparent plate, as shown in the model in Fig. 1. In this model, the dispersion angle δ decreases as parameter H_o/r decreases even if incident angle ϕ_i is large, as shown in Fig. 2, where $2H_o$ is the pitch of neighboring spheres and r is the radius of curvature of the sphere.

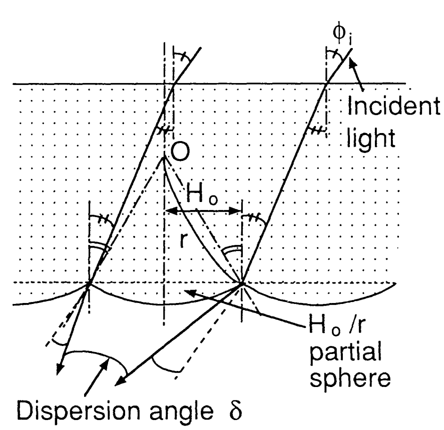

Fig. 1 Directional diffusion plate model with partial spheres.

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We tried to condense the radial image projected on this directional diffusion plate toward the viewing position on the projector's light axis by using a lens, as shown in Fig. 3(a). Consequently the right and left edge lights of the projector straight behind bend toward the center viewing position C, so a bright screen image can

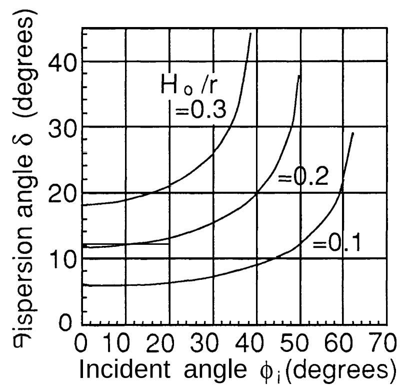

Fig. 2 Dispersion angle in the directional diffusion plate model.

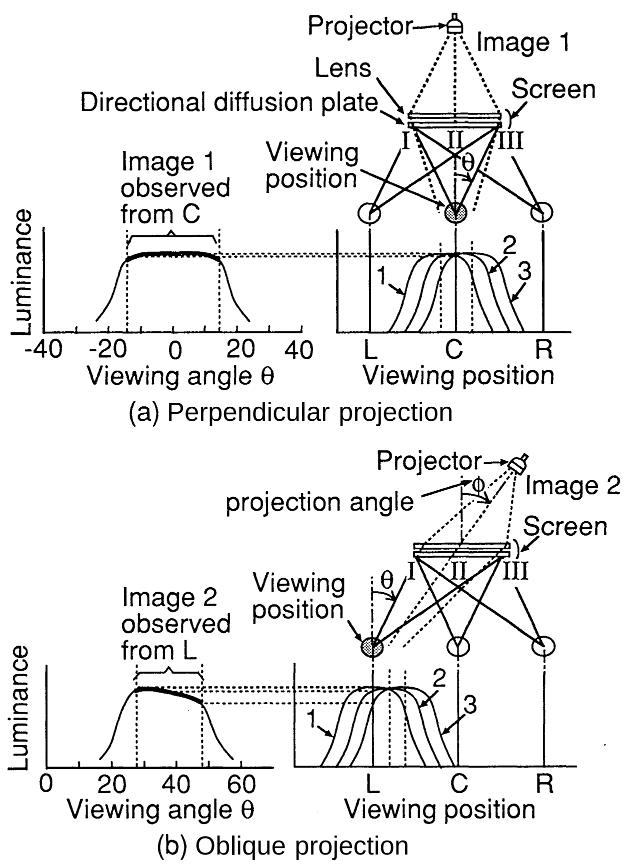

Fig. 3 Distribution of brightness on the directional screen as the projection angle changes.
(1, 2, and 3 indicate dependence of viewing position on luminance at I, II, and III respectively.)

be observed over the entire screen at position C, while the image cannot be observed at the left viewing position L or the right one R. As shown in Fig. 3(b), the image projected obliquely from the right side behind the screen cannot be observed at positions C or R, while it can be observed uniformly over the whole screen at position L.

Thus, by making the dispersion angle of the directional diffusion plate narrower than the difference in projection angles, the images projected from exactly behind and from obliquely right rear can be observed separately over the whole screen at viewing positions C and L.

2.2 Oblique Projection Image

Oblique projection causes geometrical distortion of the projected image, as shown in Fig. 4. This distortion was solved by adding inverse distortion to the image signal beforehand, because this method can be applied flexibly to distortion caused by various oblique projection angles.

We define the co-ordinates of the radial image projected on the directional screen DS made to intersect obliquely with the projector's light axis at angle $\pi/2-\phi$ as (x_s,y_s), and co-ordinates of the radial image projected on a virtual screen VS that perpendicularly intersects the axis as (x_v,y_v). This image on the VS is similar to the image of the displaying element in the projector. The image displayed on the DS is undistorted as a result of correcting the image of the displaying element by correction indices ρ_x and ρ_y.

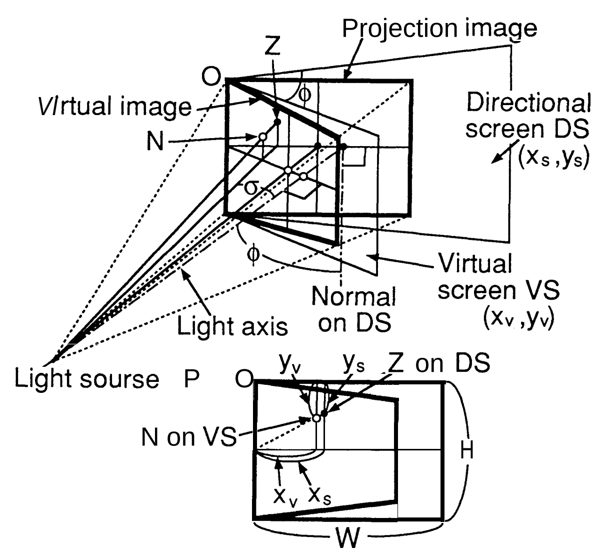

Fig. 4 Radial image light projected obliquely from light sourse toward directional screen.

$$\rho_x(x_s)=\cos\phi+\sin\phi\bullet(w/2-x_s\bullet\cos\phi)/(x_s\bullet\sin\phi+l_1),$$

and

$$\rho_y(\sigma)=l_1/(l_1+l_2)\bullet|\tan\phi+\cot\sigma|/(|\cos\sigma|(l_1+\cot^2 s)^{1/2}),$$

where l_1 is the distance from the light source P to the virtual screen. W is the corrected directional screen width, l_2 is $W/2\bullet\tan\phi$, and σ is $\cot^{-1}(l_1/(W/2-x_v))$. Accordingly co-ordinate conversion equations for correction are obtained as

$$x_v=\rho_x(x_s)\bullet x_s, \qquad y_v=H/2-\rho_y(\sigma)\bullet(H/2-y_s),$$

where H is the height of the DS. The analog image signal is first converted into digital image data. Then, the digital data for address (x_s,y_s) is written in a frame memory at address (x_v,y_v) read from the address map created by using the co-ordinate conversion equations. Thereafter, the written data is read sequentially from the memory, sent to the projector, and displayed as an undistorted image on the DS.

Oblique projection also causes defocusing of the projected image. The defocusing was solved by tilting the displaying element in the projector at an angle ω corresponding to the inclination ϕ of the screen.

$$\omega=\tan^{-1}(l_1\bullet\tan\phi/((l_1+l_2)\bullet W/w+l_2)),$$

where w is the width of the displaying element.

3. Multidirectional Picture Shooting and Multiprojection

Figure 5 shows a one-directional flow of images from location A to location B as many participants

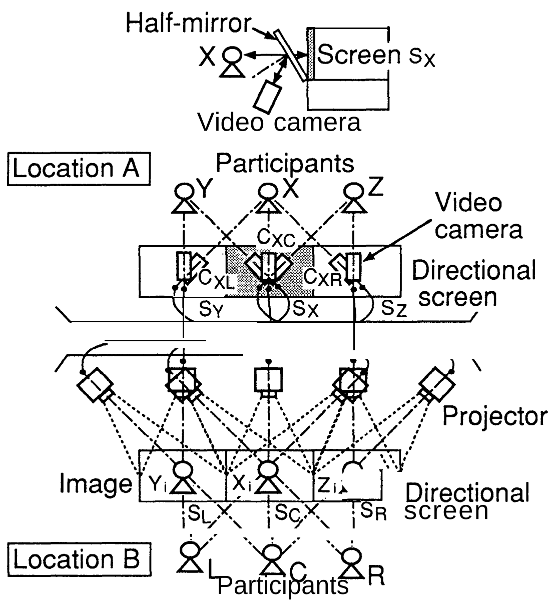

Fig. 5 Video conference system using multidirectional picture shooting and sets of the new display apparatus.

(Y, X, Z), (L, C, R) converse with each other in the video conference system. Images Xi of a participant X taken from three different angles are multiprojected onto the same directional screen S_C, which is seen by participants L, C, and R from angles corresponding to the shooting angles of video cameras C_{XL}, C_{XC}, and C_{XR}. This allows participants at each location to talk face-to-face.

In the actual interactive system, the projectors, directional screens, and video cameras are set at each location, and a half-mirror is set in front of each screen. The projected image axis and the camera axis can be matched by shooting the reflected image of this half-mirror, so participants at each location can make eye contact with each other.

4. Display Apparatus Design

We developed an apparatus for the design conditions described below by adapting the oblique projection angle ϕ and projection lengths L_p and L_o to the dispersion angle δ and focal length f respectively.

(i) The dispersion angle δ of the directional diffusion plate applied to the directional screen is 34° at the incident angle ϕ_i = 35°. When the radial images are projected perpendicularly and obliquely onto the directional screen, the projection angles ϕs, which are the angles at which the projector's light axis intersects the normal to the screen, are +35°, 0°, and -35°.

(ii) The lens is used to condense the radial image. The focal length f is 1900 mm.

(iii) Perpendicular projection length L_p is 1900 mm and oblique projection length LO is 2200 mm.

5. Results

Figure 6 shows the luminance characteristics of images F_p and O_p projected from exactly behind the screen and observed from directly and obliquely in front, and shows the luminance characteristics of images F_o and O_o projected from obliquely rear of the same screen and observed from directly and obliquely in front. The luminances of true images F_p and O_o measured at viewing positions on the projection direction were over 250 cd/m². The luminances of leakage images F_o and O_p measured at viewing positions different from the projection direction were both under 1% of those of images F_p and O_o when the gap between the two screens was W/5 and were 2-3% when it was W/10, where the gap is the region where projection images are not displayed between one screen and a neighboring screen in a system consisting of many screens, as shown in Fig.5.

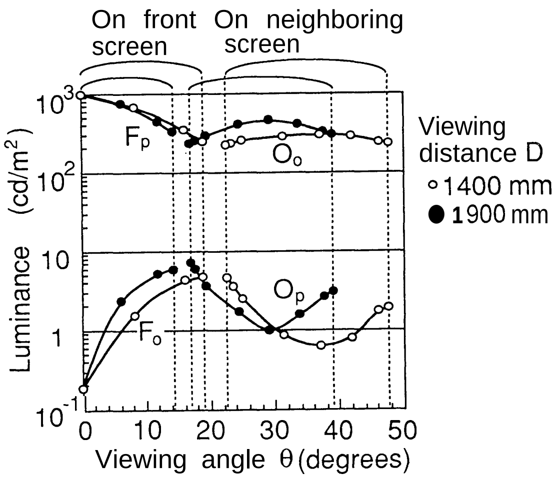

Fig.6 Luminance characteristics of the new display apparatus.

The image resolution at the edge of the screen was about 25% lower, because of the distortion correction for the oblique projection image.

Figure 7 shows examples of images displayed on the screen. These images show the appearance of two participants at position X observed from the left viewing position L, from the center viewing position C, and from the right viewing position R in Fig.5. The right person is talking with an observer at position C, and the left one is talking with an observer at position L. Figure 7(a) shows an image on the screen obliquely observed from position L, Figure 7(b) shows the image on the same screen observed in front from position C, and Figure 7(c) shows the image on the same screen obliquely observed from position R. Thus, we could obtain images that change according to viewing angle. An observer at the front position can make eye contact with the right participant in the screen, an observer at the obliquely left position can make eye contact with the left participant, and an observer at the obliquely right position sees the people talking with observers at positions L and C at an angle.

6. Conclusion

We have developed a 50-inch screen display system that produces fully separable and bright images, by condensing and multiprojecting images from various projection angles onto a directional screen consisting of a directional diffusion plate and a lens, and by correcting image distortion and defocusing caused by oblique projection. This system gives participants in teleconferences the natural feeling of being face to face.

This technique should increase the popularity and acceptance of video conference systems in the near future.

7. References

1) K. Nakazawa et al.; IEICE TRANS. COMMUN., VOL. E76-b, pp.618, 1993

(a) Observation from the obliquely left position L

(b) Observation from the front position C

(c) Observation from the obliquely right position R

Fig.7 Examples of images displayed on the new display apparatus.