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Table-top Display System Which Enables to View from Four Directions for Group Work on Round Table

Mitsuru Okumura, Kunio Sakamoto, Shusaku Nomura,
Tetsuya Hirotomi, Kuninori Shiwaku and Masahito Hirakawa

***Abstract*—The authors have researched support system of the reminiscence and life review activity. This support system consists of an interactive tabletop display and interface system. On the reminiscence and life review activity, a therapist puts pictures on the table so as to trigger a talk. However some observers may perceive upside down images if they sit down opposite the therapist. To overcome this problem, we have developed the display system which can be viewed from any direction. In this paper, we propose a 4-views display system for cooperative activity on a round table.**

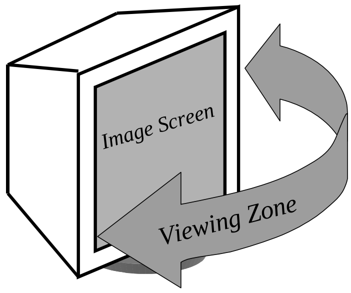
***Index Terms*— all around viewing, group work, optical grating film, table-top display**

I. Introduction

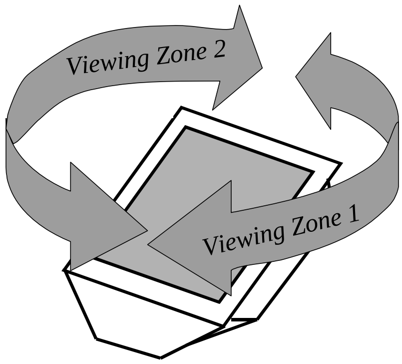
The authors have researched multimedia system and support system for nursing studies on and practices of reminiscence therapy and life review therapy. The concept of the life review is presented by Butler in 1963. The process of thinking back on one's life and communicating about one's life to another person is called life review. A therapist must keep a record of sessions for inspection of methods and ways of valuation on reminiscence and life review therapy, but it is trouble for the therapist to record. The aim of research is to develop the support system which can automatically give an optimum topic and write down a session report about the activity. This life review is often assisted by aids such as videos, pictures, objects, archives and life story books in order to make an opportunity of talking. We would like to develop a 4-views display system for cooperative activity on a round table to enable all-around viewing and unification of media contents by an electronic form.

II. Motivations

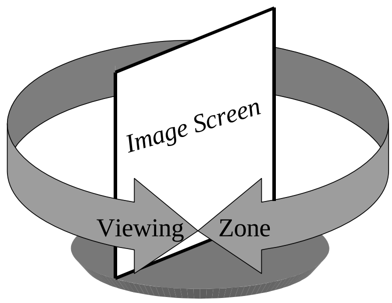
This paper describes an all-around 360 degree viewing display system that can be viewed from any direction (*i.e.*, the display has a 360-degree viewing angle). The authors have ever researched 3D display systems using the polarized glasses and the liquid crystal shutter glasses, the image splitter such as a parallax barrier or a lenticular screen and the holographic optical elements[1][2][3]. However, a conventional monitor display is viewed from one direction, that is, the display has narrow viewing angle and observers cannot view the screen from the opposite side. Hence we developed a tabletop display system for collaborative tasks cooperated by two users[4]. This tabletop display can provide different images to two users surrounding the system



(a) Conventional monitor



(b) Dual view display



(c) 360 degree viewing system

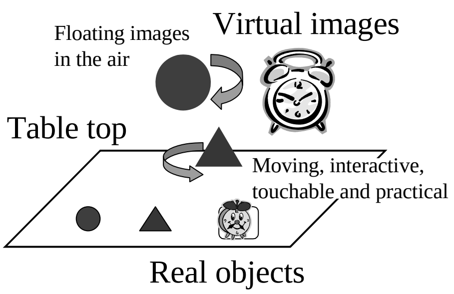
Fig. 1 Viewing zones of our display systems

M. Okumura and K. Sakamoto are with Konan University, 8-9-1 Okamoto, Higashinada, Kobe 658-8501, Japan (e-mail: kunio@konan-u.ac.jp).
S. Nomura is with Nagaoka University of Technology, 1603-1 Kamitomioka, Nagaoka 940-2188, Japan
T. Hirotomi, K. Shiwaku and M. Hirakawa are with Shimane University, 1060 Nishikawatsu-cho, Matsue, Shimane 690-8504, Japan

utilizing the image splitting technologies for displaying a stereoscopic 3D image. The viewing zones of these displays are shown in Fig. 1. But screens on the monitor cannot be viewed correctly by all users from any direction. Thus, conventional display systems enable users not to do collaborative tasks on the round table. To solve this problem, we developed the 360 degree viewing system.

We have researched the mixed reality(MR) and the augmented reality(AR). Fig. 2 shows the concept of an interactive tabletop floating image display system. As shown in this figure, users are surrounding the round table and view an image, which is on the center of a table and is floating in the air. One of the usages is to discuss on the round table for collaborative tasks as shown in Fig. 2(a). This display can provide some images according to the user's request. Suppose this system is in the science and technology museum. When kids put objects on the table, the display system gives users virtual 3D images and the observers can touch these floating images. As shown in Fig. 2(b), this system interacts; these virtual images are automatically moving according to circumstances. And the users and floating images take mutual action when the user touches the virtual image. Thus this system displays the same color and shape virtual image as the user puts an object on the table. Moreover, it is possible for users to indicate the attributes such as active motions and functions. For example, the system displays the virtual image of a clock, which is moving punctually, when the user puts the card, on which is drawn the picture of a clock. In this case, the function is to display the clock and the motion is to rotate the hour and minute hands exactly.

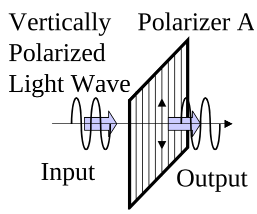
(a) collaborative tasks on the round table



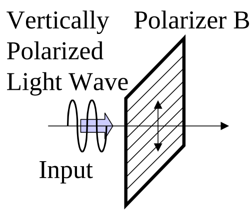
(b) interactive tabletop display

Fig. 2 Desktop floating image display

The authors firstly developed the dual views display system[4]. This dual views display enables two users to provide different images on the screen. Using this display system, each user can perceive the correct screen image without upside down images. The dual view display produces the collaborative task environment for two users. But screens on the monitor cannot be viewed correctly by all users from any direction. Thus, we have developed a display system with a 360-degree viewing angle.



(a) Vertical



(b) Horizontal

Fig. 3 Polarizer

III. OPTICAL TECHNIQUES

A. Polarizer

There are two types of polarizing filters, polarizers for short: linear and circular. Fig. 3 shows the basic concept of polarization using the linear polarizer. In this example, the linearly polarized incident light is vibrating vertically before encountering the polarizer, a filter containing long-chain polymer molecules that are oriented in a single direction. Only the incident light that is vibrating parallel to the polarization direction is allowed to pass. Therefore, since polarizer A is oriented vertically, it only permits the vertical waves in the incident beam to pass. However, the vertically polarized waves are subsequently blocked by polarizer B because it is oriented horizontally and absorbs all of the waves that reach it due to their vertical orientation.

B. Grating sheet

The authors found an interesting material at Tokyu Hands in Shinjuku, Tokyo, Japan. Tokyu Hands is one of the more interesting Do-It-Yourself type stores in Japan. There are many interesting gadgets, gifts, hobby or craft items you might want. The item, which we found, is the optical film and it is named "SOLF". The SOLF optical sheet is a flexible film with prisms designed to transport and diffuse the light. This prism sheet diffracts two beams. These beams are called as the first order diffracted beam and the second order diffracted beam.

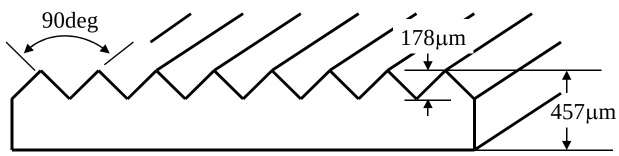


Fig 4 Structure of optical grating sheet

Fig. 4 shows the structure of the optical grating sheet. A grating diffracts or scatters a light beam with a designed angle. This sheet has interesting characteristics as follows; the prismatic phenomenon is observed and the doubling can be visible through the sheet like the Calcite. This doubling phenomenon occurs because the prism sheet diffracts two beams. This sheet provides us with a doubling image as shown in Fig. 5. Using this characteristic, the authors shift the images for displaying virtual images of LCD displays at different space from original positions by adjusting the interval between an optical sheet and an image plane of the LCD panel.

Fig. 5 Doubling phenomenon

IV. 4-VIEWS DISPLAY UNITS

To enable all-around viewing from four directions, a virtual screen is generated and floating above the top level of an actual display panel as shown in Fig. 6. Many techniques have been ever proposed in order to float images and locate pseudo images at different places from original positions. To simplify an optical layout, the authors utilize a grating sheet. As shown in Fig. 7, the grating sheet provides a diffracted image which is arranged under or above original position. The grating sheet diffracts or scatters a light beam with a designed angle. This interesting phenomenon reminds us of method to shift image positions by a simple optical layout.

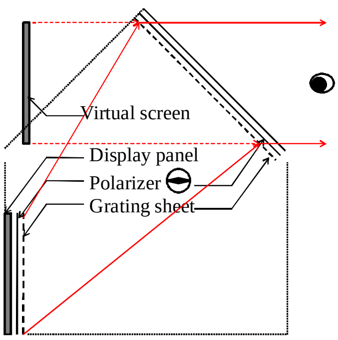


Fig. 6 Optical layout of 4-views display(KNB-10)

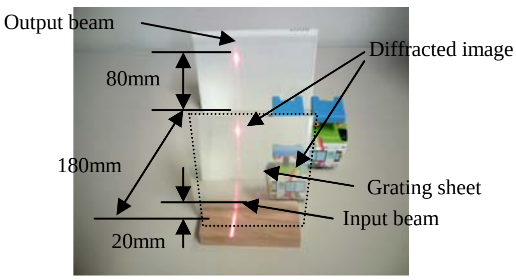


Fig. 7 Grating sheet

As shown in Fig. 6, our developed a 4-views display system consists of four LCD panels and a square pyramidal optical screen. Fig. 8 shows a display unit and its layout constituted of four panels. Fig. 9 shows a square pyramid for generating four virtual screens above original positions of the actual display panels. An LCD display produces their image by having a liquid crystal layer that when a current runs through the pixel, it turns on that shade of color. The problem with the liquid crystal is that this color can only be accurately represented when viewed straight on. The further away from a perpendicular viewing angle, the color will tend to wash out. Thus, LCD displays have a limited viewing angle. As an observer watches a viewing screen on the panel with overlooking through the grating sheet, it loses contrast and becomes hard to read at out of the viewing angle as shown in Fig. 10(a). The snapshot of Fig. 10(a) is taken from upward diagonal direction. To correct visual clarity of an LCD's viewing screen, the LCD panels are covered with the grating sheet because a grating diffracts a ray into upwards and downwards. Although the snapshot of Fig. 10(b) is taken from upwards at same angle, it has more contrast and is easier to read at out of the viewing angle using the grating sheet.

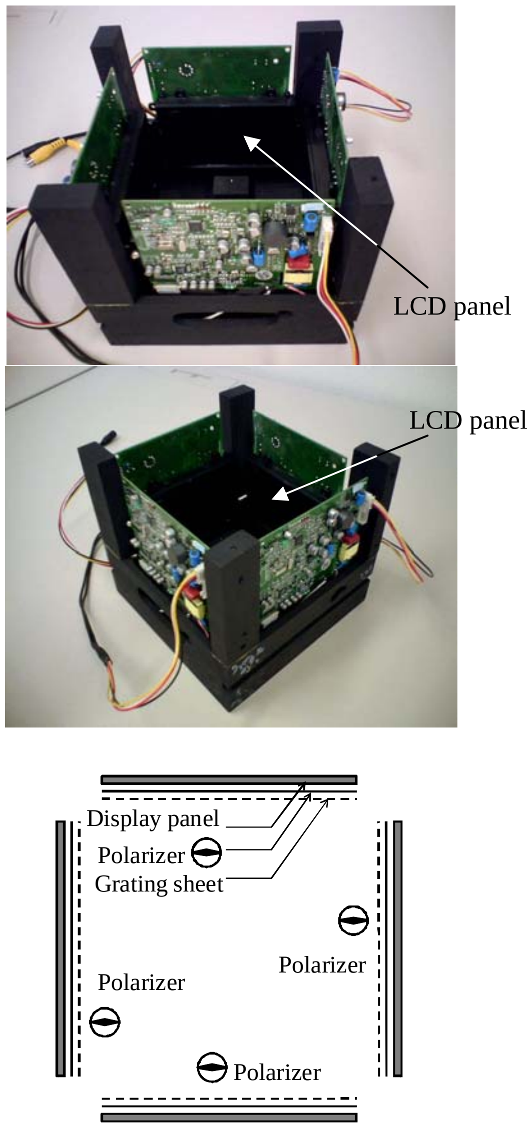


Fig. 8 Display unit

Fig. 9 Square pyramid

A square pyramidal optical screen consists of four grating sheets on its surface so that the four virtual viewing screens are floating in the air. We shaped the viewing screen into a solid pyramid in order to enable all-around viewing from any directions. The grating sheet on the pyramid surface drifts a viewing screen in front of an observer’s face. But an observer perceives not only a front view but also neighboring views. To solve this trouble, it is necessary to block lights of both neighboring views. Although louver film can also restrict a viewing angle, we utilized polarizers in consideration for easiness to obtain. The polarizer can switch whether a light goes through or not. If polarizers oriented at 90 degrees to each other, no light gets through. Meanwhile the polarizer passes a light wave when arranged for the same directions. As shown in Fig. 8 and Fig. 9, the LCD panel and the pyramid surface are covered by polarizers. For example, the horizontally oriented polarizers are attached on north and south display panels and east and west panels are covered with the vertical polarizers. North and south pyramid surfaces are also covered with the horizontal polarizers. East and west surfaces have the vertical polarizers too. The lights of both neighboring LCDs are blocked by the polarizers because polarizers on the LCD panel and the pyramid surface are oriented at 90 degrees to each other. An observer can perceive the only forward display through polarizers which have the same direction of polarization.

(a) no grating sheet

(b) grating attached

Fig. 10 Effect of grating sheet

V. Current Working Model

We have developed the prototype display system using four commercial LCD panels. These displays have a 4 inch LCD panel and its size is 82mm(W) x 61mm(H). The video input supports NTSC. The panels are fixed on edges of a 100mm square. Each panel is covered with a 100mm square polarizer so as not to perceive neighboring monitors on both sides. Moreover, a 100mm square grating sheet is attached on the panel in order to improve visual clarity. The square pyramid is made of an acrylic resin plate. Its base plane is a 110mm square and height is 105mm. This pyramid is located 60mm above top level of the view screen. The pyramid surface is also covered with a polarizer and a grating sheet. Since a polarizer blocks a light with orthogonal polarization and neighboring monitors emit polarized rays at right angles, an observer perceives an only virtual screen right in front of his/her face. Observers can watch the screen of a display from any direction because this system has four display panels with four viewing directions.

VI. Floating Display

A floating display generates a touchable virtual image in the air above the table as shown in Fig. 2. This 3D technique, frequently used in exhibitions and magic shows, employs a convex lens or concave mirror to form a realistic image close to the observer. This technology typically uses 2D images for dynamic image-floating systems.

Fig. 11 shows two parabolic mirrors for generating a floating virtual 3D image. Using the dual parabolic mirrors, the generated virtual 3D image is floating in the air. The optical phenomenon is shown in Fig. 12. This virtual 3D object maker is really two parabolic mirrors with identical shapes. The bottom mirror lays face-up on the table while the upper mirror, which has a hole in its center, lays face-down on the bottom mirror. These mirrors are designed so that the focal point of one lies just at the vertex of the other when they are placed on top of one another.

An object placed at the center of bottom mirror will be at the focal point of upper mirror. Light from the object reflects off of upper mirror into parallel paths. This light shines on bottom mirror, reflects, and converges to the point f_B. This light makes a real image at f_B.

Fig. 11 Dual parabolic mirrors

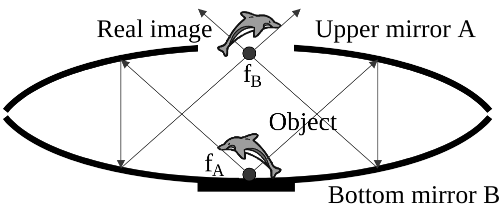


Fig. 12 Principle of generating 3D image

You place any small object or objects in the lower mirror, taking care to center them. Next, you set the upper mirror on top, being sure that both mirrors fit very well. Instantly, the objects appear floating above the mirrored circle, in full color and three dimensions. If you look at the hole of upper mirror, you'll see the object appear to hover at that point. This floating 3D object can be viewed from 360 degrees, but you can't touch it, because it's not really there.

In order to float an image screen of the 360 degree viewing display, we utilized the optical phenomenon of these parabolic mirrors as shown in Fig. 13. As shown in Fig. 13, the screen panel only sticks out of the bottom mirror and the rotating mechanism hides under the mirror. While this panel is rotating at a uniform speed, the observers directly can view an image of the panel, which is above the bottom mirror, from any direction. Using the dual parabolic mirrors, the virtual screen happens to be in the hole in the upper mirror and can be viewed from any direction because an image of the object put on the bottom mirror is made to appear in the upper mirror's focal point.

Fig. 13 Floating display with parabolic mirrors

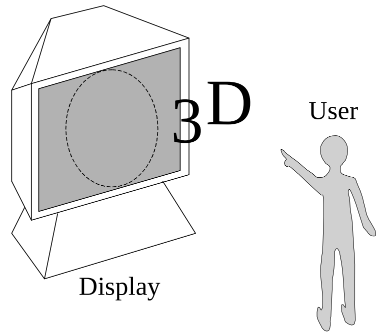


Fig. 14 Floating image display with convex lens

A floating lens also generates tangible virtual image in the air as shown in Fig 14. This principle of imaging is based on the optics of a convex lens. Note that each lens has two focal points - one on each side of the lens. The lens converges the ray at the focal point as shown in Fig 15. The generated image by the lens screen can be observed at the restricted regions where an observer watches the floating image and the lens on a straight line.

The convex lens serves to direct each image into the specific direction. This image generation of the convex lens is also based on this principle as shown in Fig 15. Real images occur when objects are placed outside the focal length of a converging lens. A real image is illustrated in Fig 15. Ray tracing gives the position of the images by drawing one ray perpendicular to the lens, which must pass through the focal point, and a second ray that passes through the center of the lens, which is not bent by the lens. The intersection of the two rays gives the position of the image. A third ray could be drawn which passes through the focal point on the left side of the lens; after passing through the lens, it would travel

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parallel to the axis, and would intersect the other two rays at the point where those rays already intersect. Note that the real image is inverted. The position of the image can be found through the equation:

$$1/d_O + 1/d_I = 1/f$$

Here, the distances are those of the object and image respectively as measured from the lens. The focal length f is positive for a convex lens. A positive image distance corresponds to a real image, just as it did for the case of the mirrors. However, for a lens, a positive image distance implies that the image is located on the opposite side from the object.

Fig. 16 shows the optical layout of a floating display system. This display consists of four LCD panels and convex lenses. A pair of display and lens generates a floating image in front of a lens as shown in Fig. 17. In the prototype display, the interval of the display and the lens is 400 mm. The floating images are generated about 350 mm apart from the lens. Fig. 18 shows the appearance of a trial display system. Since this display has four image units, observers can perceive four different images from corresponding directions around the table.

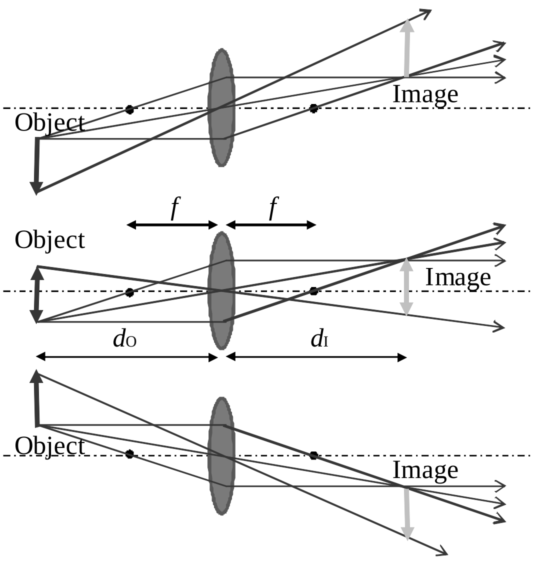

Fig. 15 Lens optics for generating real image

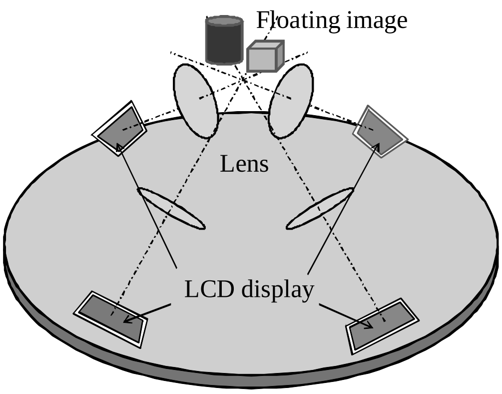

Fig. 16 Optical layout of floating image display

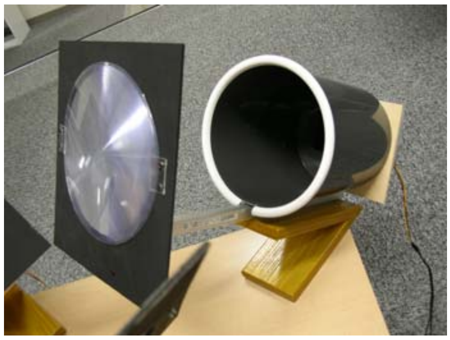

Fig. 17 Floating image generating unit

Fig. 18 Floating image display system(KNX-30)

VII. CONCLUSIONS

We developed the all-around 360 degree viewing display which can be viewed from any position surrounding the round table. These display systems are useful for working collaborative tasks among users surrounding the table. The goal of our researches is to construct a 3D workspace system using the floating 3D images which can be touched by users and can be located in the air apart from the table. The proposed display systems cannot provide the 3D image, but it is possible to improve the 3D imaging technique. These problems of improvement are our future work.

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