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Omni-directional Flat Tabletop Display Which Enables to View from Any Direction

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***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 tabletop flat display system for cooperative activity on a round table.**

***Index Terms*— all around viewing, group work, viewing angle control 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 utilizing the image splitting technologies for displaying a stereoscopic 3D image. 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.

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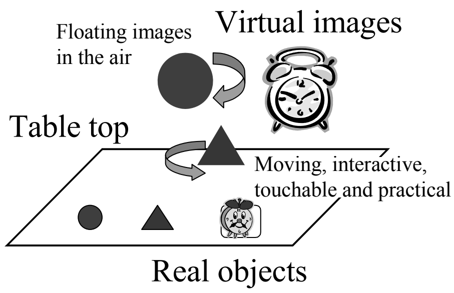
(a) collaborative tasks on the round table



(b) interactive tabletop display

Fig. 1 Desktop floating image display

We have researched the mixed reality(MR) and the augmented reality(AR). Fig. 1 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. 1(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

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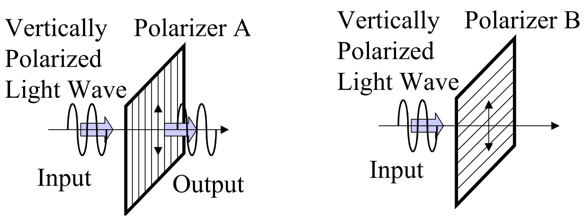
users virtual 3D images and the observers can touch these floating images. As shown in Fig. 1(b), this system interacts; these virtual images are automatically moving according to circumstances. And the users and floating images take mutual action when the user touches the virtual image. Thus this system 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.

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. 2 Polarizer

III. Optical Techniques

A. Polarizer

There are two types of polarizing filters, polarizers for short: linear and circular. Fig. 2 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.

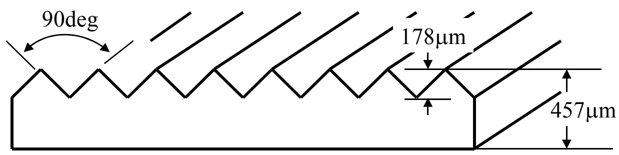


Fig 3 Structure of optical grating sheet

Fig. 3 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. 4. 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. 4 Doubling phenomenon

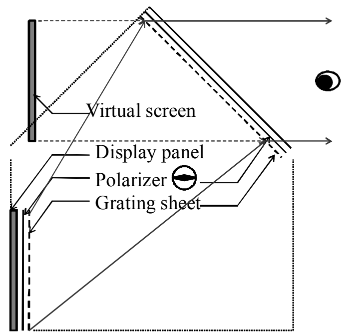


Fig. 5 Optical layout of 4-views display(KNB-10)

IV. Pyramid-top 4-views Display System

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. 5. 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. 6, the grating sheet provides a diffracted

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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.

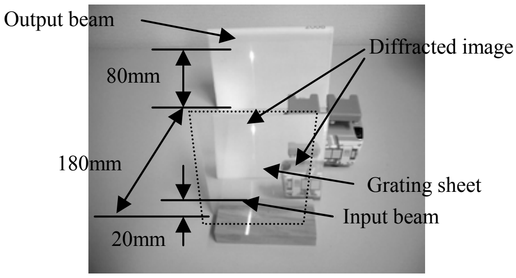

Fig. 6 Grating sheet

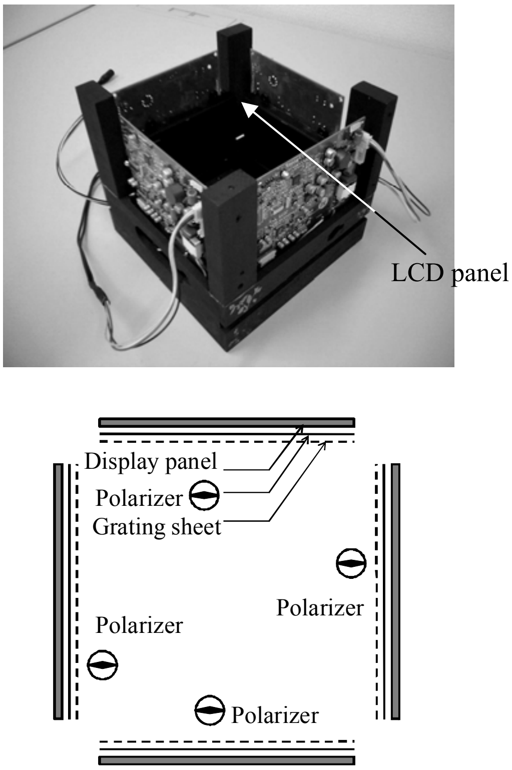

Fig. 7 Display unit (I)

As shown in Fig. 5, our developed a 4-views display system consists of four LCD panels and a square pyramidal optical screen. Fig. 7 shows a display unit and its layout constituted of four panels. Fig. 8 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. 9(a). The snapshot of Fig. 9(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. 9(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.

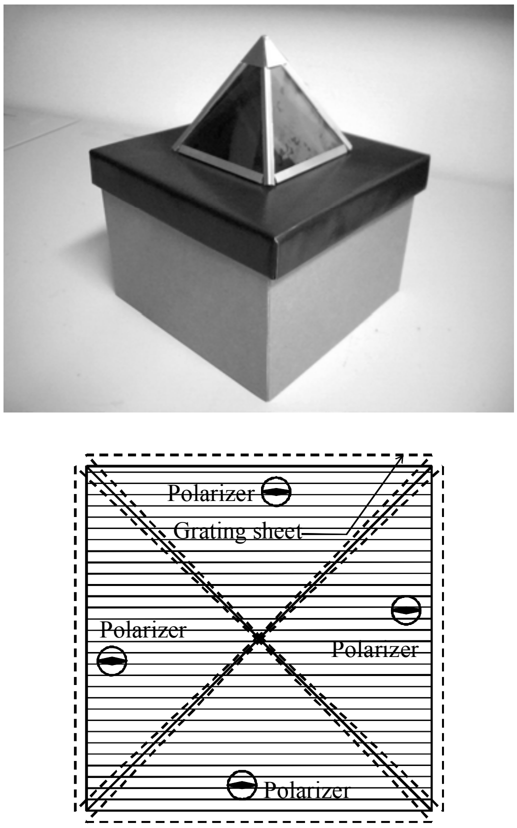

Fig. 8 Square pyramid

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. 7 and Fig. 8, 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.

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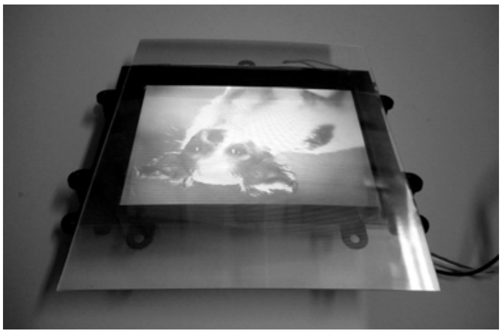
We have developed the prototype display system using four commercial LCD panels. These displays have a 4 inch LCD panel and its size is 82mm(W) x 61mm(H). The video input supports NTSC. The panels are fixed on edges of a 100mm square. Each panel is covered with a 100mm square polarizer so as not to perceive 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.

(a) no grating sheet



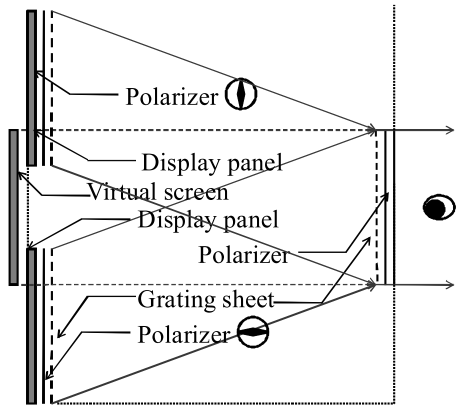
(b) grating attached

Fig. 9 Effect of grating sheet

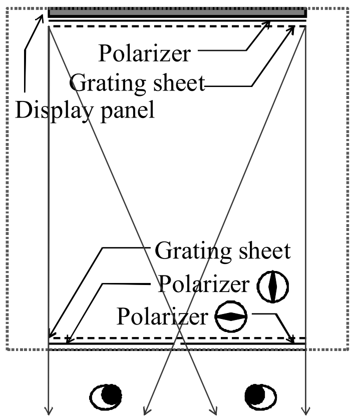
V. Improvement For All-around 3D Viewing

The tabletop display KNB-10 can provide different images to four users surrounding the system utilizing an optical grating film for generating a virtual screen and floating above the top level of an actual display panel. The floating virtual screens of this display are generated into a square pyramid in front of observers' eyes. But this system can display only 2D views which are viewed correctly by all users from any direction. Then this chapter describes an omni-directional 3D display system for the all-around viewing.

To enable all-around 3D viewing from four directions, it is necessary to generate a virtual 3D screen. So this 3D viewscreen is floating above and sinking below the top or under level of an actual display panel as shown in Fig. 10. The authors utilize a grating sheet for locating pseudo images at different places from original positions the same as the display KNB-10.



(a) side view



(b) top view

Fig. 10 Optical layout of 3D display(KNA-10)

As shown in Fig. 10, our developed omni directional 3D display system consists of eight LCD panels, an optical grating film for overlapping stereoscopic images and orthogonal polarizaers for separating left and right images. Fig. 11(a) shows a display unit and its layout constituted of four panels. This unit produces a left or right image of 3D view. To show left and right images, two display units are piled as shown in Fig. 11(b). Fig. 12 shows the appearance of our developed prototype display.

As shown in Fig. 10, two display panels are arrayed vertically in order to produce left and right images. A grating film appropriately locates apart from the panels so as to shift both images into the same position for superimposing stereoscopic images by adjusting the interval between the optical sheet and the display panels. Orthogonal polarizers work as an image separater for delivering left and right images into appropriate eyes. The lights of an LCD pass through the polarizers or are blocked by the polarizers whether eyes are corresponding to each image or not. An observer can perceive the left and right image through polarizers which have the same direction of polarization. Thus you can see the 3D image without special glasses.

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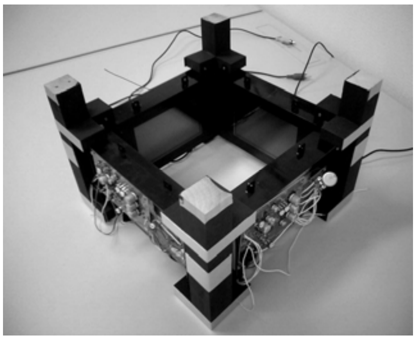
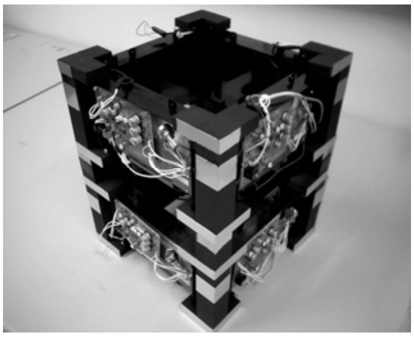


(a) display module



(b) piled module

Fig. 11 Display unit (II)

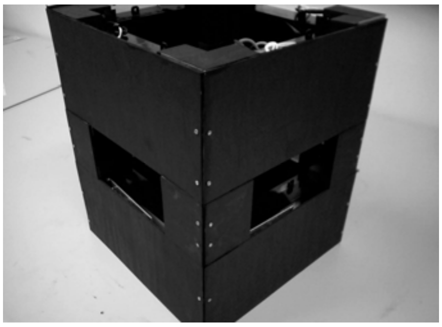


Fig. 12 Appearance of omni-directional 3D display

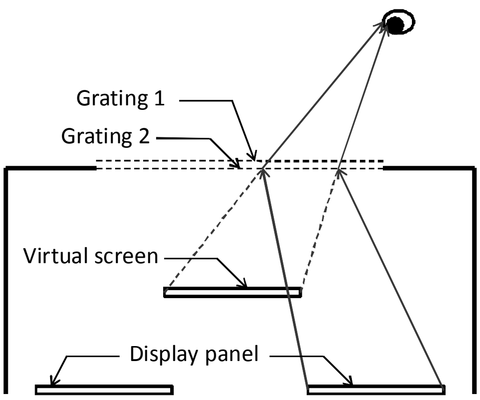
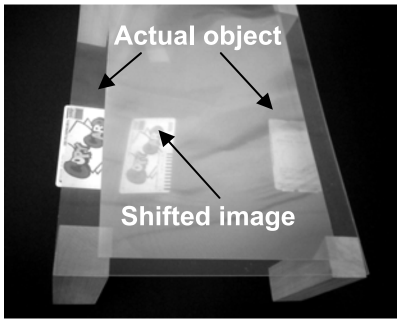
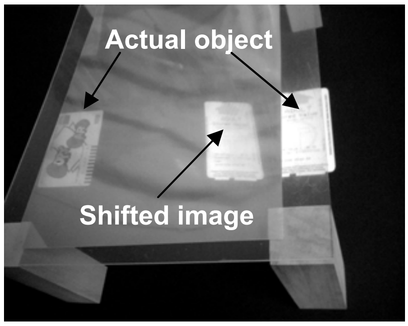


Fig. 13 Optical layout of 4-views display



(a) view from left



(b) view from right

Fig. 14 Image shift by grating sheet

VI. Newly Developed Flat-type Tabletop Display

The authors firstly used the "SOLF^{TM}" optical grating sheet for shifting and floating image planes above the top level of an actual display panel. This display system is the shape where the outer surfaces are triangular and converge at a point as shown in Fig. 8. We would like to shape a new display like a conventional table. To enable all-around viewing from four directions, it is necessary to generate a virtual screen. So this viewscreen is floating above an actual display panel and sinking below the level of the table as shown in Fig. 13. To simplify an optical layout, the authors utilize a special grating sheet for locating pseudo images at different places from original positions. The author unexpectedly found this special sheet at the Sannomiya store of Tokyu Hands. As shown in Fig. 14, this grating sheet provides a diffracted image which is arranged left or right from 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. This product name is unknown. We regard this sheet as a cheaper copy product of the SOLF sheet. However this sheet has a useful characteristic. Using this film, you can observe shifted image of the left card from the left, but not from the right as shown in Fig 14. The right card is also observable as the same. Thus this new grating film has an effect of the viewing angle control in addition unlike an original SOLF sheet.

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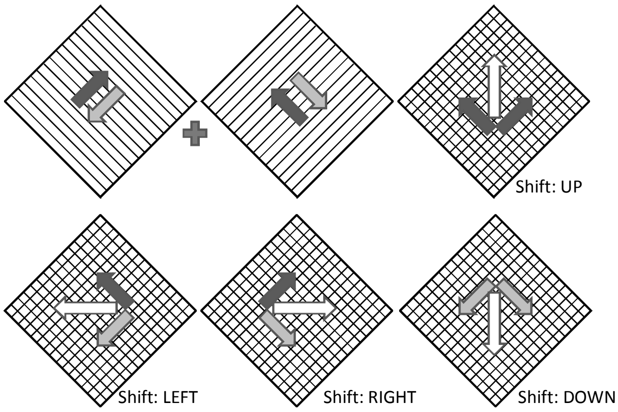

Fig. 15 Effect of image shift to four directions

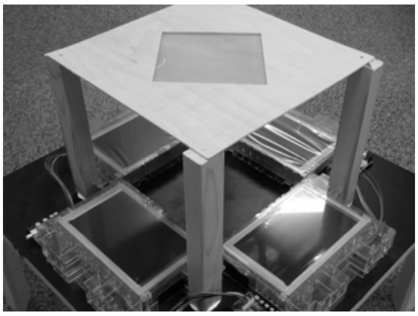

Fig. 16 Appearance of tabletop display (KNB-20)

As shown in Fig. 13, our developed omni directional display system consists of four LCD panels and two optical grating films for shifting original images into the center and separating virtual images into an appropriate eye. As above mentioned, one grating sheet can shift left and right images into the center and deliver each image to an observer. To generate four virtual screens, we piled up two grating sheets. The important point is that each sheet is inclined at 45 degrees to an edge of the table because both sheets shift the images into any direction independently. As shown in Fig. 15, the combination of two optical sheets generates four directional image shifts. Each grating sheet shifts an actual image into any direction at 45 degrees to horizontal. Both image shifts makes vertical shift as the result. Other image shifts are also generated just the same. Fig. 16 shows the appearance of our developed prototype display. Four display panels are arrayed crosswise in order to produce four virtual image screens into the center. A grating film appropriately locates apart from the panels so as to shift images into the center for delivering an appropriate image into each observer by adjusting the interval between the optical sheet and the display panels. The lights of an LCD pass through the films or are blocked by the films whether eyes are corresponding to each image or not. An observer can perceive delivered image without wearing special glasses.

We have developed the prototype display system using four commercial LCD panels. These displays have a 7.24 inch LCD panel and its size is 160mm(W) x 90mm(H). The video input supports NTSC. The panels are fixed on edges of a 220mm square. The size of a viewing window on surfaces of the table is 150mm square. This viewing window is with two grating sheets. The distance between these LCD panels and the viewing window is approximately 220mm so as to shift all images into the center. Since the grating sheet not only shifts an image but also controls a viewing angle, 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 screens with four viewing directions.

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