Stereoscopic Display with Recurrent Viewpoints Using Hologram of Multiple Focal Points

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(Received October 15, 2001)

Synopsis

A pair of viewpoints is almost fixed in the case of stereoscopic vision without glasses, which causes inconvenience to an observer. This paper proposes a 3-D display system, by which the same stereoscopic image can be observed from many horizontal directions. The holographic display is experimented by arranging many light sources for the object beams. The several technical problems involved in the exposure process of the holographic optical element are concretely examined.

KEYWORDS: Stereoscopic display, Multiple focal points, Holographic display, 3-D display

1. Introduction

A 3-D image is more naturally visible when compared to a plane image, and acts strongly on human sensitivity and emotion. In recent-years, the progress of research on image-processing technology and stereoscopy, has enabled us to get the device that displays 3-D moving image. [1] The holography that has a function of continuous parallax in its 3-D image display has no inconsistency in convergence and regulation, and provides us with the natural stereo effect. However, the holographic moving display involves a huge amount of information, and is difficult to be realized.

In this paper, we proposed a 3-D display with which one can observe a stereogam from many horizontal directions. This is realized by applying the hologram that is made using many object light source to the stereogram.

The stereo-type stereoscopy without using glasses is inconvenient for an observer, since the observation point is fixed. Moreover, the common stereogram has only two viewpoints, and then only one person can make use of it at a time. The same is true for observation of the stereo image on the screen using the hologram. In this case, the observation point is determined by the position of object light source at the time of photographing. Therefore, in order for two or more persons to be able to observe simultaneously, it is necessary to set up large number of observation points. In the case of hologram, it is achieved by carrying out a multiplex exposure by changing inclination of a film plate gradually. However, the multiplex exposure causes a lowering of the diffraction efficiency of the hologram and an observation under a general lighting turns out to be difficult. To overcome this, it has seen proposed that a pixel unit is distributed along each direction. [2] A defect of this method is that, as the number of parallax directions increases, the number of pixels per one direction decrease and the quality of image deteriorates.

In this paper, we propose a method of increasing a number of viewpoints without making lows quality of image. The key idea is a repetition of giving a same set of stereogram at a time to the observers. We arrange a pixel by using the slit-division method, and made a holographic optical element in the display by using plural object light sources. When observation is made, as long as each eye is in the corresponding observation pupils, one can catch a stereoscopy even if the position of the eyes are not strictly fixed. Moreover, plural persons who sit in right and left can observe the same stereoscopy simultaneously.

2. Composition of the System

As the reproduction with the holographic optical element, conjugate reproduction is occasionally made, in which the illuminating light is of opposite direction to the reference light at the photography. In this case, the reproduced diffraction light condenses into the position of the original object-light source. That is, the position of an image of the object light source turns out to be the position of the observation point. Therefore, multi-viewpoint hologram may be made by increase the number of the object light sources when taking the photograph.

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Then, as shown in Fig.1, we consider the correspondence of one pixel versus many viewpoints both for the left-eye part and the right-eye part. An advantage of this system is to be sufficient to make only two original images, the one for the right and the one for the left. Furthermore, despite the many viewpoints, the pixel size of the images needs not to be very fine. In order to realize the system of, there must be plural object light sources. However, the optical system constituting of many beam-splitters groups turns out to be complicated, and then we use a combined parallel-plane mirrors and one object light source. [3]

The photographic optical system with a single stereo viewpoint is schematically shown in Fig.2. After the first exposure, we move the slit mask in one unit and carry out the second exposure. When moving the mask, the position of object light source for the left eye and the right eye are changed. At the reproduction, the slit images of the position L condense in a left eye, and the slit images of the position R condense in a right eye. We then project the mixed images which are made as the illuminating light of hologra from the back of a drawing hologram. In this manner, a pair of stereoscopic images consisting of the image for the right eye and the one for the light eye in provided.

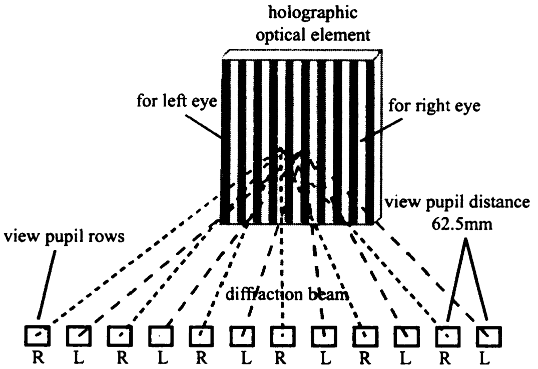

Fig.1 Display with viewpoints

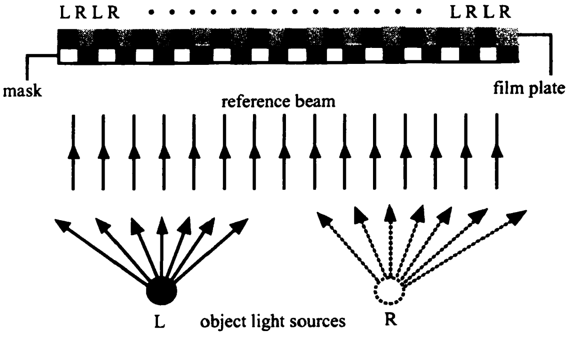

Fig.2 Exposure for a pair of viewpoints

The system with many viewpoints is shown in Fig.3. The hologram is exposed by two plane mirrors M_1 and M_2 which install in parallel. The object light sources consist of the multiplex virtual image (broken line) group of a single object light source. The whole optical system is shown in Fig.4.

The distance between the two parallel plane mirrors (300mm × 300mm), M_1 and M_2 are set to be about 62.5mm, that is the distance between a pair of adult's eyes. For the purpose of the setting the size (100mm × 125mm) of a hologram plate was also taken into consideration. The object light source (diffusion light source, 20mm × 60mm) is set up close to the one of the two plane mirrors at the opposite position to the hologram plate. Setting the slit mask on the leftmost position and using the plane mirror close to the object light source for the left (or right) viewpoint, one takes a photo. Then one moves the slit in one unit and changes the position of object-light source for the right (or left) viewpoint, and takes the second photo. At the time of reproduction, the viewpoint for left eyes and the viewpoint for right eyes can arrange by turns in the unit of distance between eyes. One adjusts the image of the contiguous object-light source for right eye and that for left eye, so that they completely are set each other at the

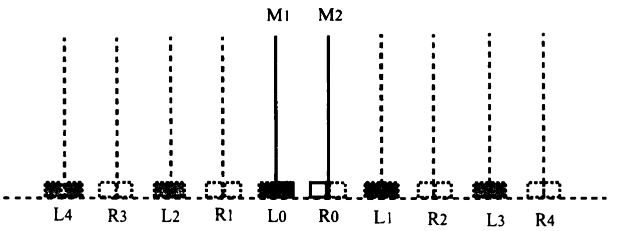

Fig.3 Scheme for recurrent viewpoints

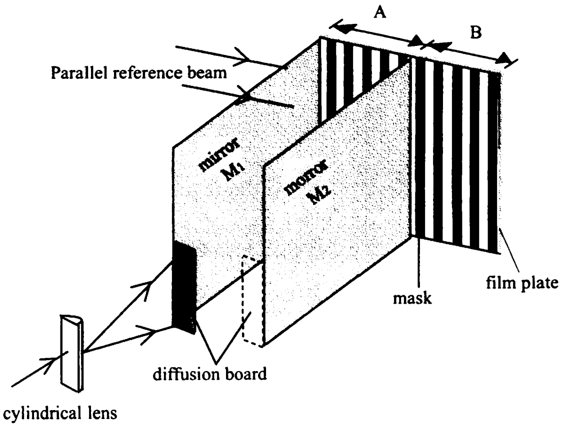

Fig.4 Layout for exposure

place near the boundary of the reflective side of mirror. In order to prevent the appearance of a space in the images, a plane mirror with high reflectance should be used, and a reference beam should be of parallel and should be projected in parallel to the mirror.

The width of the hologram plate is 125mm, which is twice the distance between eyes. Then, if the second exposure is performed at moving the plate by 62.5mm after the first exposure, the whole plate can be used for the purpose of reproduction of the stereogram. A number of slits, light and darkness portions total, per one exposure are 25 and the slit width is 2.5mm, so that the width of exposure side turns out to be 62.5mm. The space position in the plate exposed before and after moving the plate is different. Then a device is required when one arranges by turns the slits for right eye and the ones for left eye, such that no inconsistently arises at a boundary.

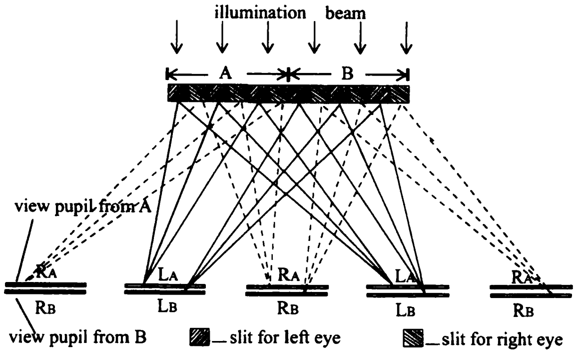

Fig.5 Generation of recurrent viewpoints

Fig.6 Separated parallax images

As shown in Fig.5, the slits for the left eye and the slits for the right eye are arranged by turns both in the A portion and in the B portion. If the slits for left eye and the one for right eye are arranged in the same way both in the A portion and in the B portion, reversion occurs at the boundary of A and B. Therefore, it is necessary to take photography of A portion and B portion in right-left contrary mann. Then, the pupil L_A for the left eye and the pupil R_A for right eye, which are reproduced from the A portion of the hologram plate, overlaps at the same position to pupil L_B for the left eye and the pupil R_B for right eye, in respective order, which are reproduced from B portion. The arrangement of the slits is also in order at the boundary of A and B.

The sheet that is used at the reproduction stage is made as follows. One slices each of the two 2-dimensional images of different parallax by a slit mask. The area of the sliced picture is the half of the effective area of the original picture. One compounds these two pictures to a sheet, which is used for reproduction. When we project the synthetic image that is displayed on the LCD panel on the above-mentioned hologram screen, the stereograms being divided into right and left, are condensed by turns into a horizontal direction. Then the stereoscopic observation may be make from any position or by two more persons at the same time.

In order to enlarge the image, one arranges in horizontal direction many of such screen successively, which is photographed under the same condition as A and B.

3. Experiment Result and Examination

When stereoscopic observation is made of the image of slit-division method, the parallax images that observed at the positions of a left eye and of a right eye are displayed in Fig.6. Some technical devices adopted in this research are following.

a. Making a thin mask with high quality: We first make a master mask by arranging the wires with 2.5 mm diameter at similar intervals of 2.5mm. We then put this master mask on the emulsion side of the hologram plate for masks and expose it by the incident parallel beam from the front. After development, we get a thin mask for photography. If we use this thin mask, not only the object light from the front but the object light from transverse direction can be exposed with sufficient accuracy on a hologram.

b. The reflective light from the rear surface of the plate interferes, and acts as a noise. As an object used for a light source, we choose a diffusive object whose reflectance is high along the normal direction. Weakening the brightness of the object light source, we take a photograph. In this way, the influence of back reflection can be reduced. In the experiment, the ratio of the brightness of reference beam to that of object beam is 3:1.

c. Due to the position of the viewpoint at the time of reproduction, the inclination directions of the object beam and of the reference beam are not in same plane to the hologram plate. Then, the photographic optical system is three dimensions. Thus, due to the directivity of the object light, the degree of condensation of the reproduced light to the transverse direction is debased. However, if the diffusive object light source is used the influence of directivity is reduced.

d. A faithful color reproduction is made through performing a triple-record in such a may that each of the RGB three primary colors meets the corresponding Bragg condition. Due to the form of the object light source in this experiment, reproduced light diffuses up and down. Then, we forecast that the light with fairly extensive zone is reproduced by using a white light source, although it dose not satisfy the Bragg conditions.

e. Since the different object light source results in different optical path difference, as a number of images of light sources increases, the spatial coherence of the beam is reduced and a noise arises. Then, it is necessary to restrict the number of times of multiplex reflection used for reproduction.

4. Future Subject

As stated above, there are various factors that act to reduce the diffraction efficiency of a holographic optical element in the fact. We forecast it is effective that by making use of the laser with sufficient spatial coherence length or the photography system like to the edge-lit holography.

In order to carry out color reproduction, it is required to use the triple-exposures or 3-color laser reproduction, etc.

These are future research subjects.

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