Development of 3D Display System for Video-guide Operation

Toshio Honda, Kou Suzuki, Yasuhito Kuboshima and Tatsuo Shiina
Chiba University, Faculty of Engineering, Department of Information and Image Sciences.
TEL:80-43-290-3469, e-mail: toshio.honda@faculty.chiba-u.jp

Keywords: auto-stereoscopic displays, eye-position tracking, automatic image change

ABSTRACT

In the constructed auto-stereoscopic display system for one observer. 1.stereoscopic images displayed on a special LCD are made on a large concave mirror. 2.The view-zone limiting aperture is set between the projection lens and the concave mirror. 3.The real image of the aperture is made at the observer's eye position by the concave mirror. 4.The observer's eye-position tracking of the view-zone is realized. 5.At same time, stereoscopic image changes automatically according to the eye position of the observer.

1. Introduction

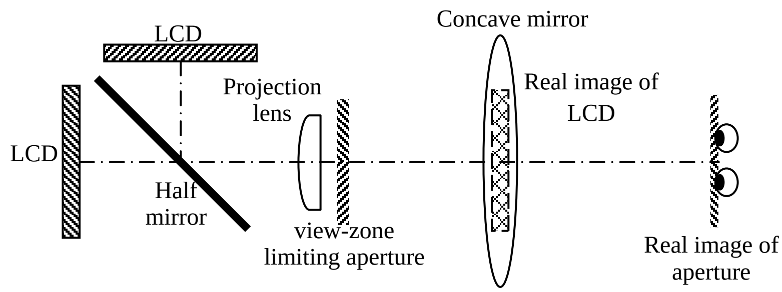
Development of the 3D video display wearing no special glasses for one observer (operator) who can use for remote manipulation support has been desired. However, in almost auto-stereoscopic displays, the position at which an observer can see 3D image (the area of the position is called “view-zone”) is restricted to narrow area. In our system, in order to expand the view-zone detecting the 3-dimensional position of the observer's eye, the view-zone is moved to the position of the observer's eyes By this technology, wide 3D image observation volume is realized in horizontal, vertical, and front and behind directions for video guide operation.

2. Principle of the auto-stereoscopic display system

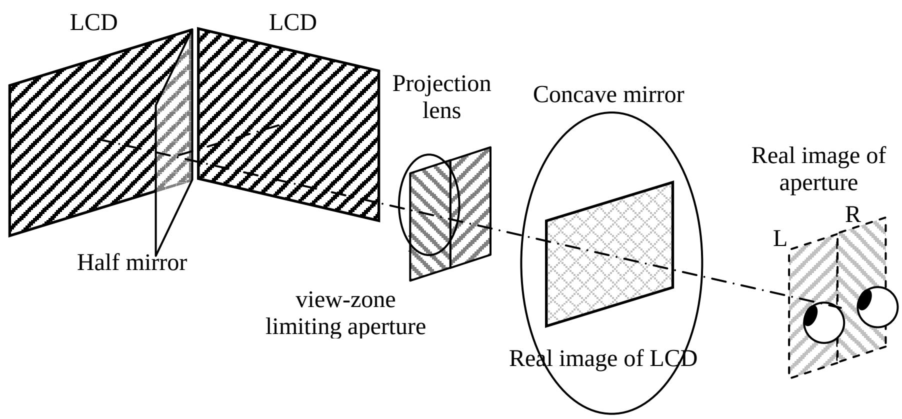
The 3D display system which realizes auto-stereoscopy is shown in Fig.1(a) and (b), schematically. In these figures, the concave mirror is drawn as a convex lens for easy understanding. The stereoscopic image pair is displayed on two LCD panels. Images on two LCD panels are combined by a half mirror, and polarization directions of linearly polarized light from two LCD panels are set perpendicular each other. The combined real image is formed on the concave mirror by a projection lens.

Between the projection lens and the concave mirror, two polarization plates are set as shown in Fig.1. Directions of the polarization of two polarizers are set perpendicular each other, and each direction of polarization is aligned same as that of each LCD panel. We call this set of two polarizers "view-zone limiting aperture". Left side aperture passes light from right image only, and right side aperture passes light from left image only. The real image of the view-zone limiting aperture is formed at the observer's eye position by the concave mirror. When each eye of the observer is put at the real image position of the each aperture, the observer can see stereoscopic image near the concave mirror surface.

Since the concave mirror is used practically instead of a lens, the real image of the aperture is formed in the same side with the aperture. So, we set a half mirror in front of the concave mirror.



(a)



(b)

Fig.1 The conceptual figure of proposed 3D display system. (a) top view, (b) bird's eye view. In these figures, the concave mirror is drawn as a convex lens for easy understanding.

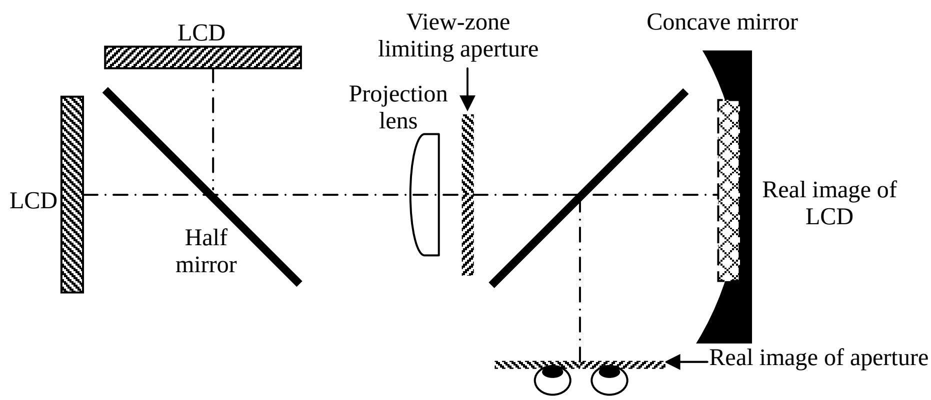


Fig.2 A conceptual diagram of the display system (Top view)

The display system which uses the concave mirror is shown in Fig.2. The reason of the use of concave mirror is as follows. A lens which has large diameter and short focal length (small F-number) is not realizable and another reason is described in the next section.

3. Expansion of the observation volume

The horizontal length of view-zone is fixed about 6.5 cm (the interval of both eyes). To widen a stereoscopic image observation volume, we try to shift the view-zone according to the movement of the observer. For the shift, eye-position tracking system is used. For horizontal and vertical movement of the observer, the concave mirror is rotated using linear-motion motors. For front and behind movement, the position of view-zone is moved by shifting a view-zone limiting aperture to the direction of the optical axis.

4. Detection of the 3-dimensional position of the observer's eyes

For accomplishing a real time eye-position tracking of the view-zone to the observer's eyes, the three-dimensional eye-position of the observer should be detected in real time. We have been developed the eye-position detection system, which has the advantage of high accuracy and non-contact [1]. The human eye has high retro-reflective feature for near infrared light. The near infrared LED light sources are set around the infrared camera lens, and the camera takes an image of observer's face. The camera is placed under the concave mirror. The bright image of the observer's eye pupils can be taken, and the pupil position from the image is obtained with image processing by a computer. Moreover, the distance between the observer and the camera is determined from the interval of pupils.

5. Construction of the practical display system

As a practical display system, we used a special LCD panel called "μ-pol" panel. In the panel, the direction of the polarization is perpendicular each other in each scanning line. The image of left eye is displayed on even scanning lines of the LCD panel, and that of right eye is displayed on odd scanning lines, respectively. And using the view-zone limiting aperture mentioned previously, right side aperture passes light of left image only, and left side aperture passes light of right image only. The one μ-pol LCD panel serves as the same function instead of two LCD panels shown in Fig.1 and 2. Practical parts with

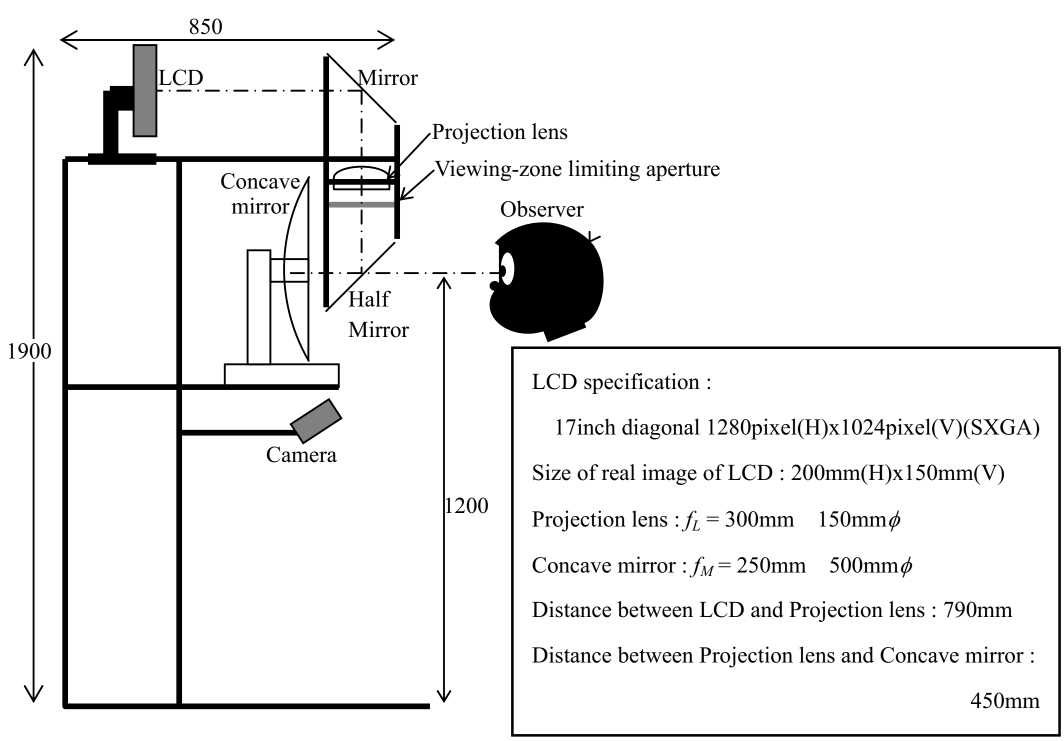


Fig.3 Practical Construction of the display system (Side view)

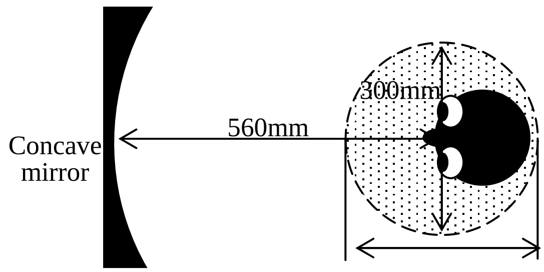


Fig.4 stereoscopic image observation volume (Top view)

which the display system is consisted are arranged
vertically. This composition of display system is shown in Fig.3. The observation volume which is widened by the shift of view-zone tracking is + - 150mm horizontally, + - 100mm vertically, + - 150mm front and behind from the central position (Fig.4)

. 6. The stereoscopic image displayed in this system

In view of real objects, when the viewer moves, image looked at by the viewer changes, continuously . In video guide operation, it is preferable that the observed stereoscopic image by the display changes according to the observer's shift. By this change, the operator can operate precisely and in short time. In this system, the position of the operator's shift is detected for the view-zone tracking. So, the change of displayed stereoscopic image can easily realized by the shift of stereoscopic video cameras. Of course, images taken by video cameras are displayed in the stereoscopic display system. When it is difficult to shift video cameras, images displayed in the system can be generated by the method of computer graphic technology. The depth image of captured images can be determined by stereo matching technologies. But these works by computer need time, and real time display is difficult in our system[2].

7. Summary

We constructed an auto-stereoscopic display system which consisted of a special LCD, projection lens, large concave mirror, and a view-zone limiting aperture. The large 3D image observation volume was obtained by detecting the 3-dimensional position of an observer's eye, and by shifting the position of view-zone limiting aperture. The movement was realized by using three linear-motion motors for the tracking of movement of the operator's eyes.

The light intensity from LCD is decreased by passage of the polarizer, and a half mirror, so, the displayed 3D image becomes dark. It can be overcome by changing a backlight of the LCD panel to stronger one. The observed stereoscopic image in the display can be changed according to the observer's movement.

REFERENCES

1. H. Imai, S.Tsujikawa and M. Imai, Proc. SPIE vol. 3639, pp. 92-97 (1999)
2. T.Honda, Y.Kuboshima, K.Iwane and T.Shiina, Proc. SPIE, 6055, p.60550V-1 - 8 (Stereoscopic Displays and Applications XIII) (2006)