Universal Stereoscopic Display Using 64 LCD's

Yasuhiro Takaki
Dept. of Electrical and Electronic Engineering
Tokyo University of Agriculture & Technology
2-24-16 Naka-machi, Koganei, Tokyo 184-8588, JAPAN
Phone: +81-42-388-7923, E-mail: ytakaki@cc.tuat.ac.jp

Abstract

A new technique to construct an auto-stereoscopic display that offers massive horizontal parallax images is proposed. Multiple telecetnric imaging systems are arranged in a modified 2D array. The horizontal parallax images displayed by LCD panels are imaged to be superimposed on a 3D screen. All parallax images are displayed in the different horizontal directions because all imaging systems have different horizontal positions. The difference of the vertical display directions due to the imaging system's vertical positions is canceled by a vertical diffuser placed at the 3D screen. Observers can percept 3D images with the binocular disparity, the vergence, and the smooth motion parallax. In addition, the accommodation function may also work because a number of parallax images are displayed with a very small angle interval in the horizontal direction. A prototype 3D display including 64 color LCD panels was constructed.

1. Introduction

The realization of a natural 3D display will bring the next progress to display industries.

A new-generation natural 3D display may be required to have following features:

(a) Simultaneous observation by several persons
(b) No need of wearing special 3D glasses
(c) Providing high presence
(d) No contradiction to human 3D perception
(e) Offering color and moving images

Considering the present device technology, the most promising candidate is a multi-view 3D display. Several horizontal parallax images are displayed into the corresponding horizontal directions. It satisfies the above requirements except (d). Observers can percept 3D images with the binocular disparity, the vergence, and the motion parallax. The accommodation function, however, does not work in the previous multi-view 3D displays.

Recently, Kajiki[1] reported that the accommodation function may work when high-density horizontal parallax images are displayed simultaneously. Because parallax images are displayed with a very small angle interval, rays actually converges in 3D space and more than one parallax images enter into a pupil of an observer's eye. When the eye focuses on the plane where a 3D object is displayed, as shown in Fig. 1(a), parallax images are superimposed one another to form a sharp image on an retina. Otherwise, a blurred image is formed as shown in Fig. 1(b). Observers are released from the fatigue, that is the fatal problem of the conventional 3D displays, caused by the conflict between the accommodation and the vergence. The difficulty is that more than 50 horizontal parallax images are required to be displayed simultaneously with a very small angle interval.

The final goal is to construct an auto-stereoscopic display which offers 3D images not contradicting to human 3D perception. A new term "a universal stereoscopic display" is introduced to distinguish it from previous stereoscopic and auto-stereoscopic displays.

In this paper, a new technique to construct a multi-

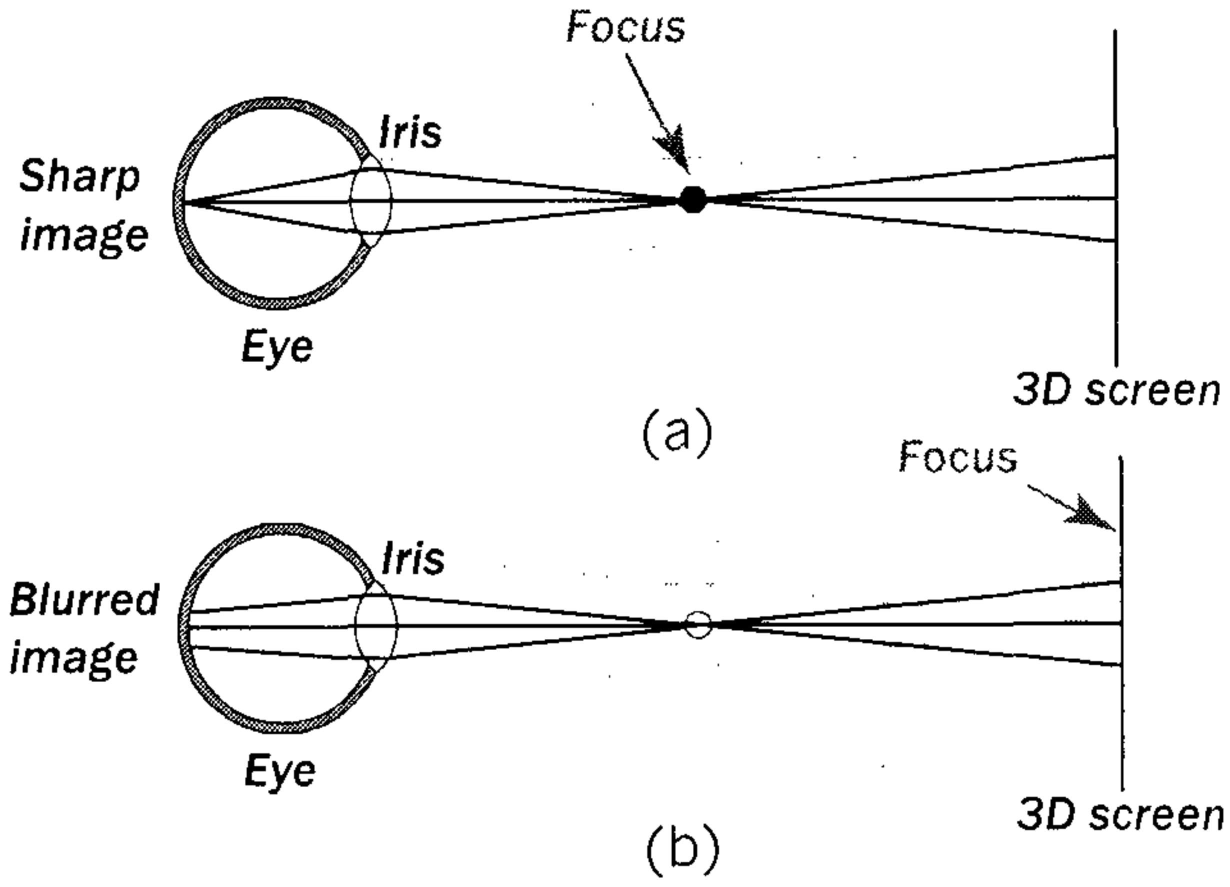


Figure 1 Accommodation may work with high-density horizontal parallax images: an eye focuses (a) on a 3D object, and (b) on the 3D screen.

view 3D display having massive horizontal parallaxes is presented. A prototype display having 64 horizontal parallaxes is reported.

2. Universal stereoscopic display using multiple telecentric imaging systems

A universal stereoscopic display using multiple afocal imaging systems is illustrated in Fig. 2. It consists of a 2D display array, a micro-lens array, an aperture array, a common lens, and a vertical diffuser (3D screen). A number of telecentric afocal imaging systems are arranged in a modified 2D array and are multiplexed through a common lens. All parallax images displayed on 2D displays are imaged at an identical position on the vertical diffuser. Because all imaging systems have different horizontal positions, all parallax images are imaged in the different horizontal directions. The difference in the vertical display directions due to the imaging system's vertical positions is canceled by the vertical diffuser. The modified 2D arrangement enables a number of parallax images to be displayed in the different horizontal directions.

Figure 3 shows the display directions of parallax images. Horizontal and vertical axes are horizontal and vertical display directions, respectively. Left figure shows the display directions just in front of the vertical diffuser. Each rectangular area corresponds to the display directions of each parallax image. Right figure shows those just behind the vertical diffuser. The common vertical viewing zone for all parallax images is produced, although all parallax images have different horizontal display directions. This figure also shows that the modified 2D arrangement enables non-display horizontal directions to disappear. The existence of those is an inherent problem in the previous multi-view 3D displays.

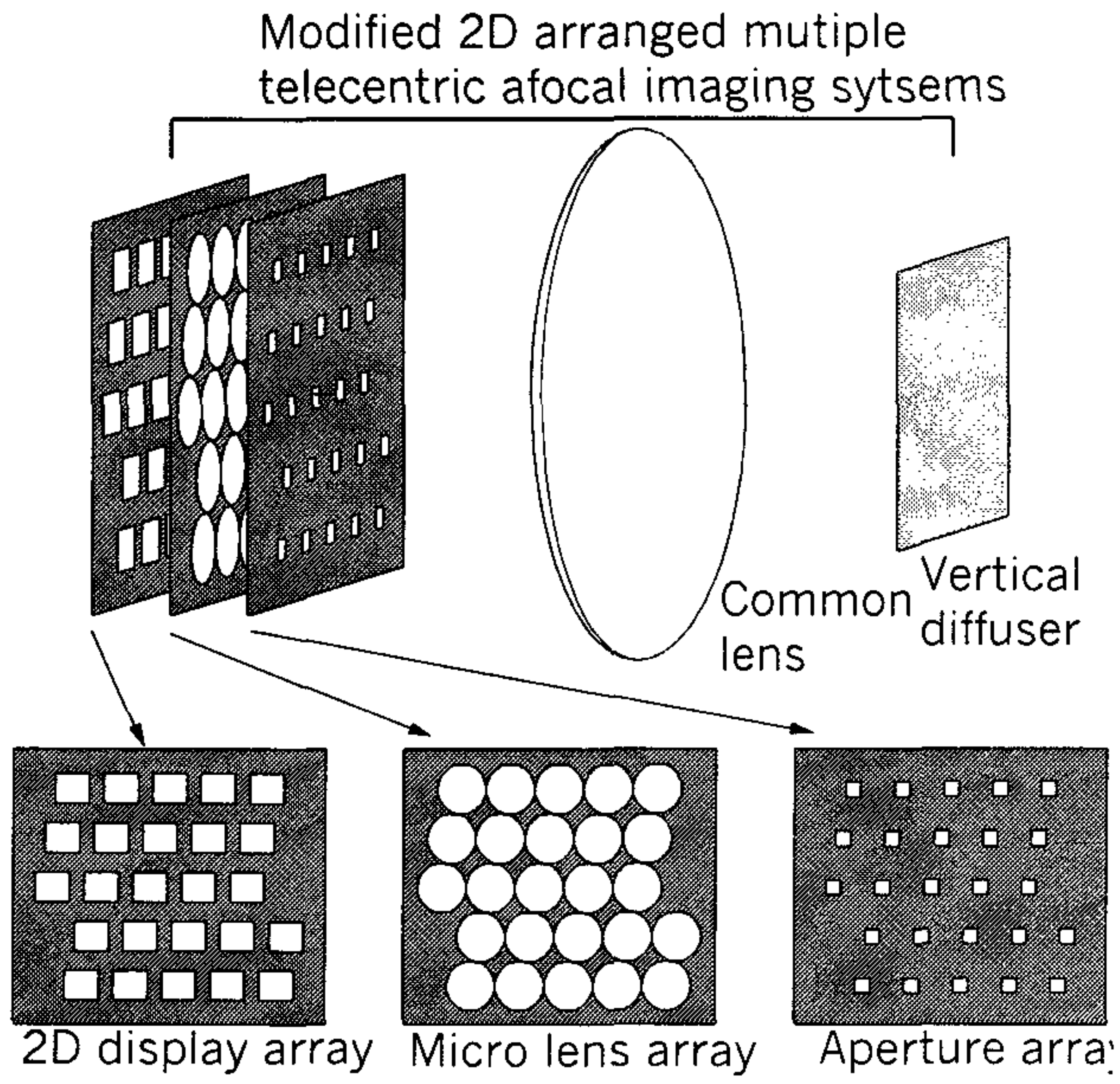


Figure 2 3D display using multiple telecentric afocal imaging systems arranged in a modified 2D array.

The important point is that the telecentric imaging systems are used for the image formation. The aperture array controls the angular display widths in the horizontal direction of parallax images. The angular display width for each parallax image is very small because the number of parallax images is large. Consequently, the parallax images are defocused a

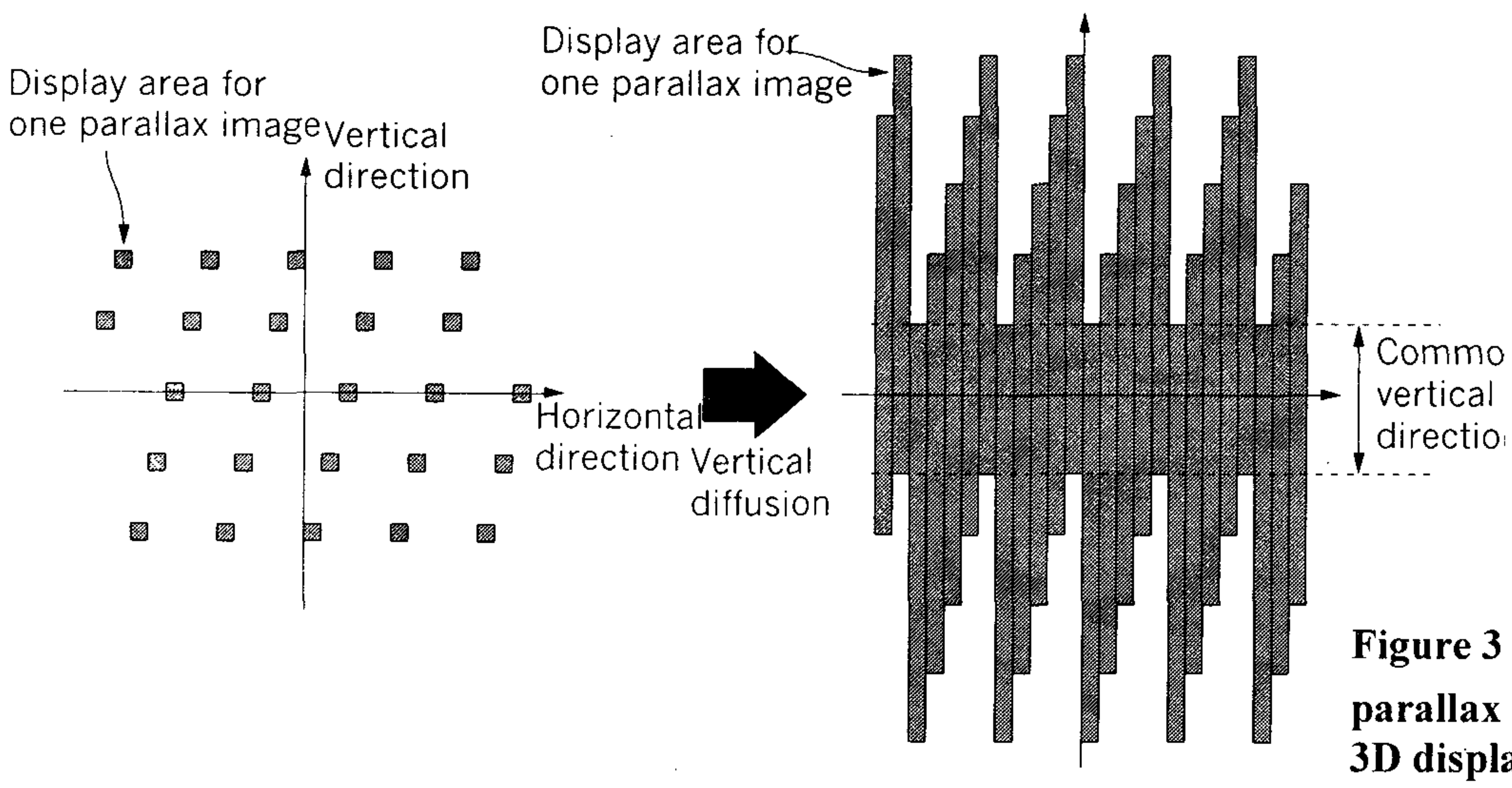


Figure 3 Display directions of parallax images of the proposed 3D display technique.

Table 1 Specifications for a prototype universal stereoscopic display

Number of parallaxes	64
Horizontal parallax interval	0.33 deg
Horizontal viewing zone angle	20.8 deg
3D screen size	192 mm X 152 mm (9.6 inch)
Frame rate	30 Hz

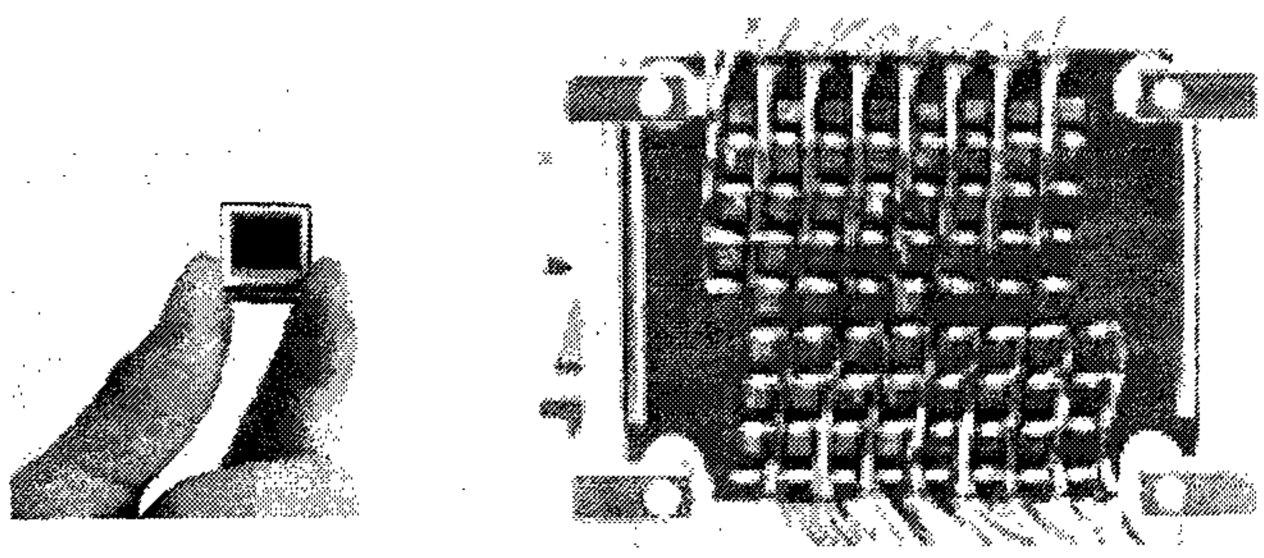
little when leaving from the 3D screen. The observers can see clear 3D images even when 3D images are produced apart from the 3D screen.

3. Prototype system

The specifications for a prototype 3D display are shown in Table 1.

A 0.55 inch color LCD panel was used as a 2D display (see Fig. 4(a).) The LCD has 180,000 pixels and the frame rate is 30 Hz. The photograph of the modified 2D arranged LCD panels (8x8) is shown in Fig. 4(b). The LCD array was controlled by eight PC's and each PC drives eight frame memories.

A Fresnel lens was used as the common lens, and a lenticular sheet was used as the vertical diffuser.



(a) (b)

Figure 4 LCD array; (a) 0.55 inch color LCD, (b) modified 2D arrangement.

In the micro-lens array, the LCD array, and the aperture array, their components are arranged on the identical planes. The installation holes are precisely drilled on aluminum plates and the components are put in them. The alignment was done between the three plates, the Fresnel lens, and the lenticular sheet.

The parallax images were rendered by using a computer graphics software. The camera angle was changed 64 times in the horizontal direction with the angle interval of 0.33 degree to render 64 parallax images.

The 3D images produced by the prototype system were captured by a CCD camera with several horizontal angles. The photographs are shown in Fig. 5.

The universal stereoscopic display can produce 3D images in front of the 3D screen. The depth position

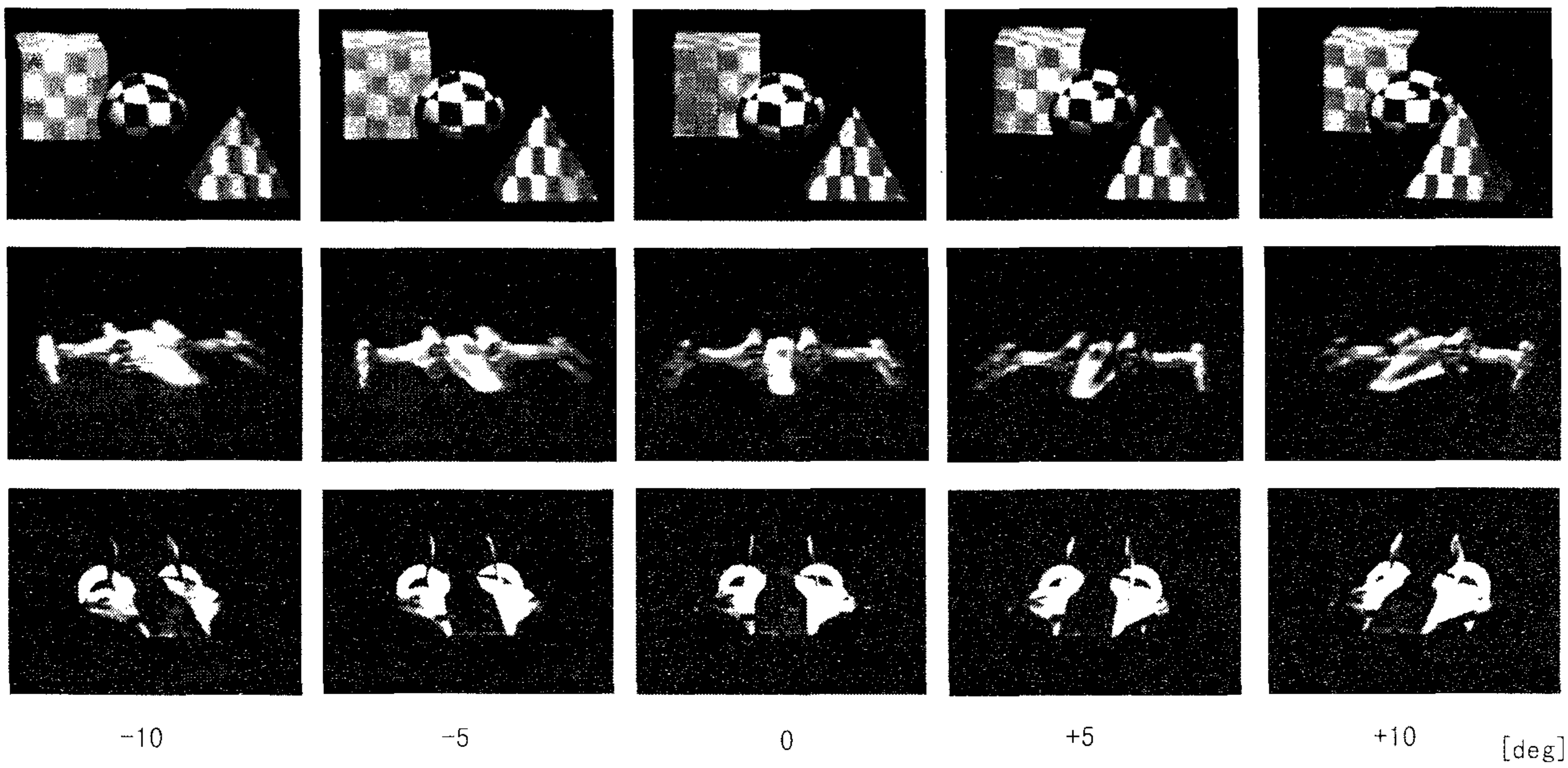


Figure 5 Photographs of 3D objects produced by the prototype 3D display.

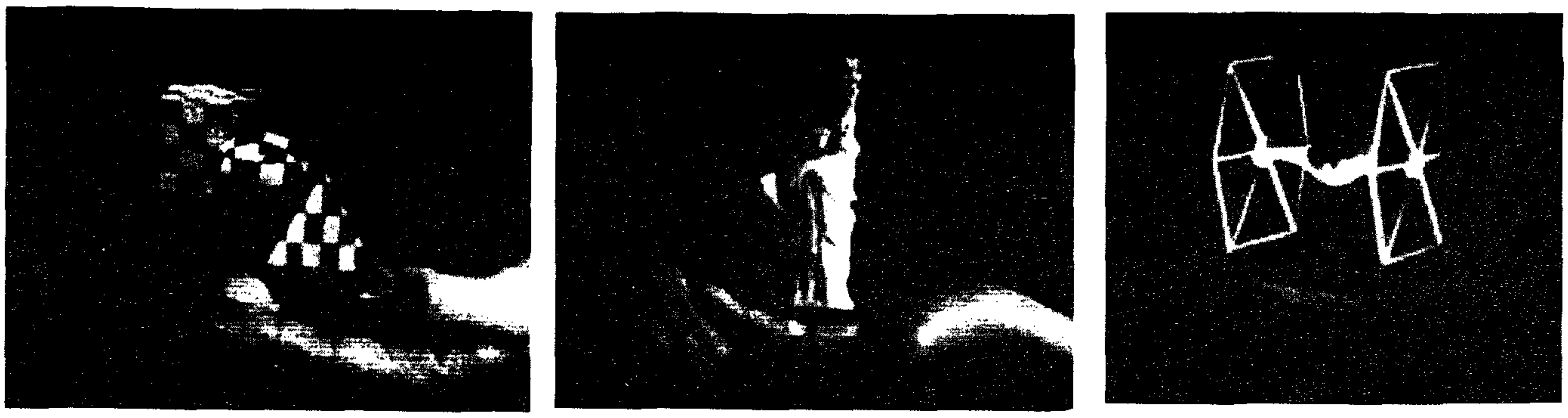


Figure 6 Photographs of produced 3D objects on a palm.

where observers percept a 3D object does not depend on observing positions. Therefore, observers can examine the position of a 3D object with their fingers as shown in the photographs in Fig. 6. The prototype system provides high presence.

4. Large screen universal stereoscopic display

Another configuration using the modified 2D arranged telecentric optical systems is shown in Fig. 7. The 3D screen consists of 3D pixels. The 3D pixel consists of a modified 2D arranged light source array, a micro-lens, and a vertical diffuser. Because the horizontal positions of all light sources are different, all rays go to different horizontal directions after passing through the micro-lens. The difference of the vertical proceeding directions of rays is canceled by the vertical diffuser. All rays emitted from the light sources proceed in the different horizontal directions. With a 2D array of the 3D pixels, a number of horizontal parallax images are displayed in the different horizontal directions. The angular display width in the horizontal direction of each parallax image is determined by the horizontal width of each light source. Because the 3D pixels can be made thinly, this configuration is suitable for a large screen 3D display.

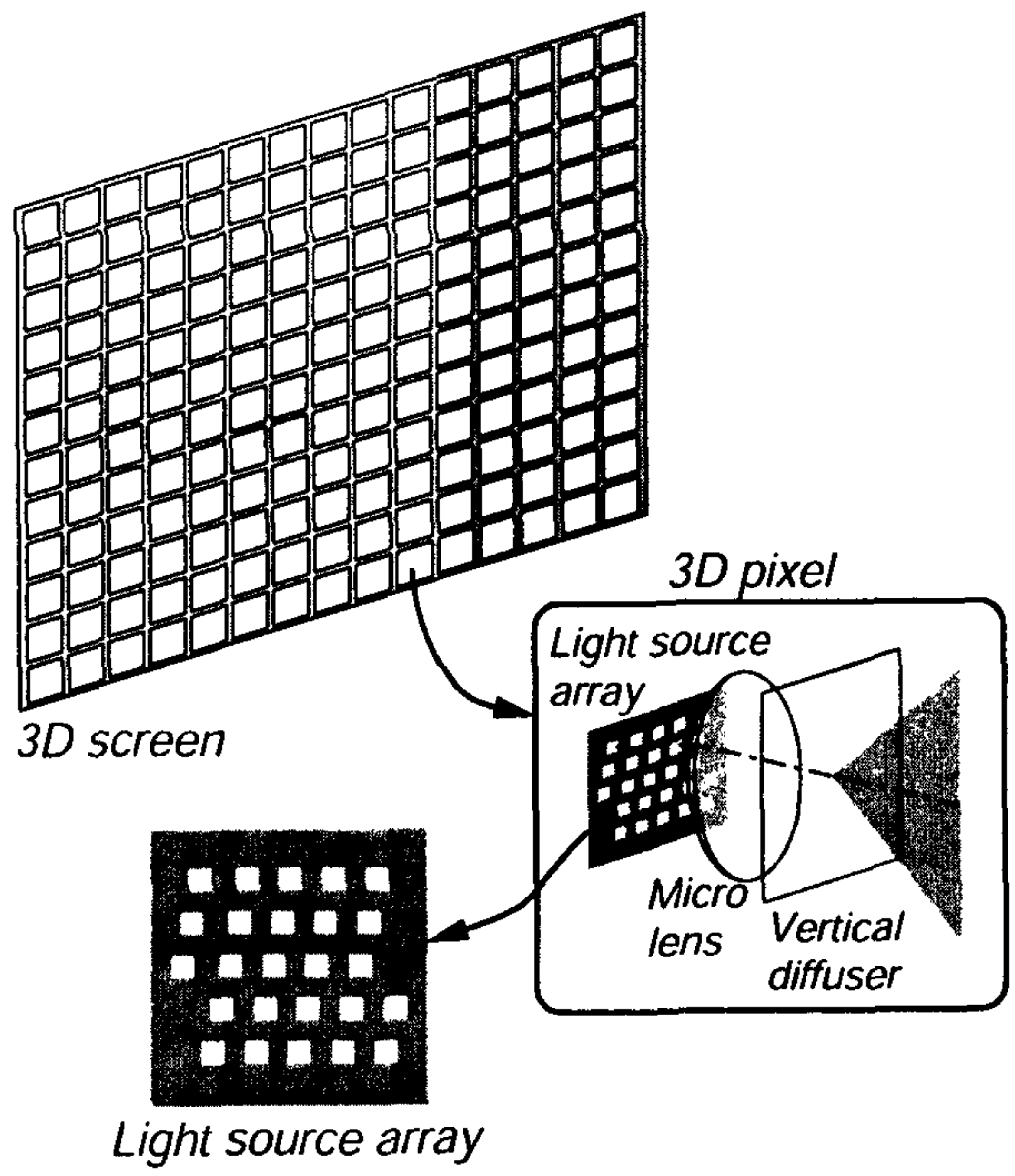


Figure 7 3D display using modified 2D arranged telecentric light source arrays.

4. Conclusion

A new 3D display technique is presented, which enables to display a number of horizontal parallax images. It uses modified 2D arranged multiple telecentric optical systems. There are two types of configurations; one uses multiple afocal imaging systems, and another uses light source arrays. The prototype 3D display having 64 parallaxes was constructed using the former configuration. The production of color 3D images was demonstrated.

5. References

[1] T.Kajiki, H.Yoshikawa, T.Honda: ``Ocular Accommodation by Super Multi-View stereogram and 45-View Stereoscopic Display," Proceedings of The Third International Display Workshops (IDW'96), 2, pp.489-492 (1996).