# 58.1: A Wide-Field-of-View 3-D Display

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## Abstract

*We developed the turn type three-dimensional(3D) display system using arrayed light emitting diodes. This system can display three-dimensional images in real space. It has wide viewing angle and has high brightness. We succeeded in the display of 3D animation. We believe that this system will find application in the field of advertisement.*

## 1. Objective and Background

Three-dimensional image can display more information clearly because it can represent depth which cannot be expressed by two-dimensional image. At present, three-dimensional image display can be divided into three types; two-eyes, holography and discrete-depth plane.

The two-eyes type is structurally simple, and its picture quality is excellent. However, it has the disadvantage that it causes fatigue of the viewer's eyes.

The holography is disadvantageous in that its displayed moving picture is difficult or impossible to view under natural light.

The discrete-depth plane has the following characteristics; this type can display images which can be seen from every direction. In addition, this type causes no eyestrain. The above has led us to become much interested in discrete-depth plane type. Our further research into this type has allowed us to propose the turn type three-dimensional display using arrayed light emitting diodes (LED).

## 2. Principle

Fig.1 shows the principle of our proposed display; 16-LEDs are arranged vertically. When the LED-array moves right and left, two-dimensional images can be viewed as a result of the afterimage effect. We applied this principle to 12-LED-arrays arranged in the depth-wise direction to represent three-dimensional image display.

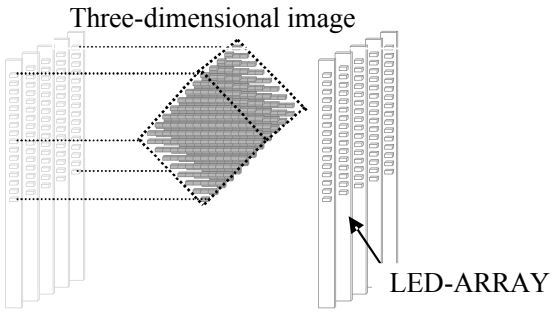



Fig.1 Principle

## 3. Proposal

Fig.2 shows the arrangement of the LED and the LED-arrays. The LED-arrays must move continuously to display the three-dimensional images. As shown in Fig.2, we arranged the LED like an arc on a turntable. As the turntable turns, the LED-arrays emit light and display an image, that is three-dimensional, and can be seen from every direction. Turning LED-arrays allows the image display to occur in the horizontal direction. Moreover, the image display can occur in the depth-wise direction when the LED-arrays arrangement is shifted in the depth-wise direction.

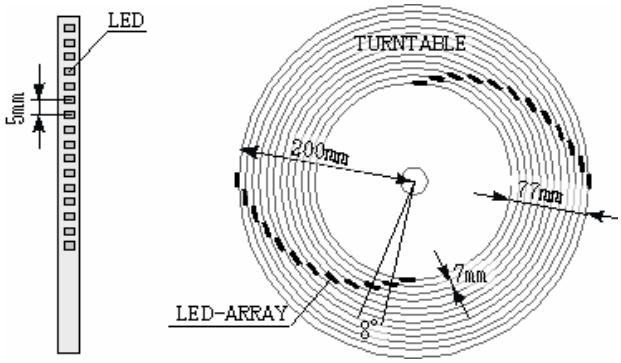



**Fig.2 Arrangement of the LEDs and the LED-arrays**

## 4. Structure

Fig.3 shows the structure of the Wide-Field-of-View 3-D Display. This display system consists of two display units, a turning mechanism and driving circuits.

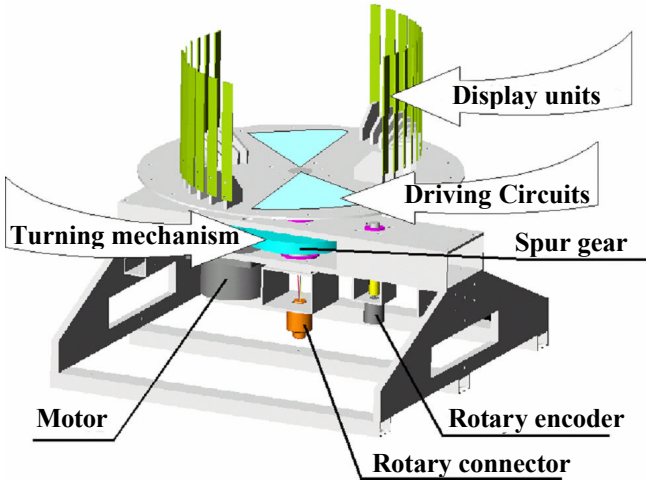



Fig.3 Structure

### 4.1 Turning mechanism

The turning mechanism is composed of a motor, spur gears, a rotary connector, a rotary encoder, and a turntable. The maximum

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speed of the motor is 3000rpm. The spur gears, which have a reduction ratio of 3 to 1, are used to increase the torque of the turntable. Therefore, the maximum speed of the turntable becomes 1000rpm, allowing the turning mechanism to be stabilized.

The rotary connector is used to supply power and sync signal to the turntable. The use of the rotary connector prevents the supply line from being twisted.

The sync signal is necessary to determine the lighting position of the display units correctly.

The rotary encoder is used for generation of the sync signal.

The ratio of the turntable to the rotary encoder is 1:2. When the turntable turns one cycle, the sync signal of two pulses occurs from the rotary encoder.

## 4.2 Display unit

Table1 shows the characteristics of the chip LED used in the display unit. The LEDs are made by TOYODA GOSEI CO., LTD. It is excellent: in brightness and wide viewing angle.

Table1 Characteristics of the LED

| Lighting color | Green |
|---|---|
| Size [vertical×horizontal](mm) | 1.5×3.0 |
| Vertical and horizontal viewing angle (degree) | 140 |
| Forward pulse voltage [V] | 3.4 |
| Forward pulse current [mA] | 45 |

Fig.2 shows the arrangement of the LEDs and the LED-arrays. The 12-LED-arrays, which are provided on each side of the turntable, are arranged in the depth wise direction at 7mm intervals and in the turning direction at 8-degree intervals. Each LED-array consists of 16-LEDs which are arranged in vertical direction at 5mm intervals. As shown in Fig.2, the LED-arrays are arranged like an arc, allowing the viewing angle to be widened.

## 4.3 Driving circuit and display method

Fig.4 shows the flow diagram of the driving circuit. The data for the three-dimensional images to be displayed are created using PC (Personal Computer). The image data are written into 12-PICs (Peripheral Interface Controller), each of which is equipped with a CPU, a memory and I/O (Input/Output), allowing reduction in the size of the circuit. The 12-PICs are attached to the turntable. Each PIC controls one LED-array on each side on turntable. The 12-PICs output the image data at the same time.

When the turntable turns one cycle, the sync signal of two pulses occurs from the rotary encoder, entering the SINC terminal of each PIC. The entry of the sync signal into the PIC causes it to output the PIC. The image data drives the driving circuits and controls the lighting of the LEDs, causing the image data to be displayed as three-dimensional images at the same time in the front and rear.

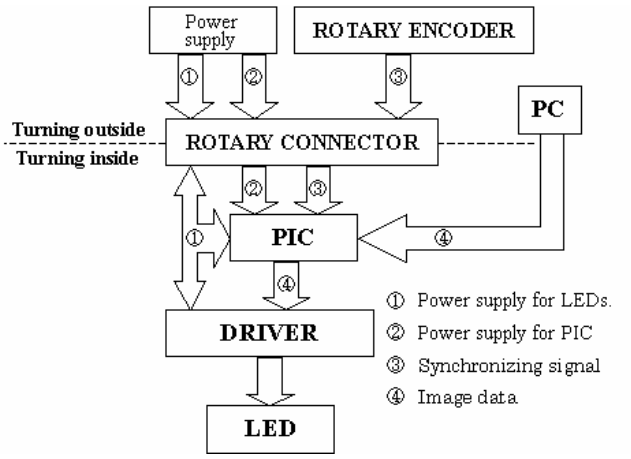



Fig.4 Flow diagram of the driving circuit

## 4.4 Program for display range correction

Fig.5 explains that the 12-LED-arrays require correction of their display ranges for proper display of three-dimensional images. The LED-arrays have different in their turn trucks became they are arranged in the arc shape. Therefore, we designed a program for such display range correction, as well as a program for pixel pitch rectification. Such correction programming software is written into each PIC.

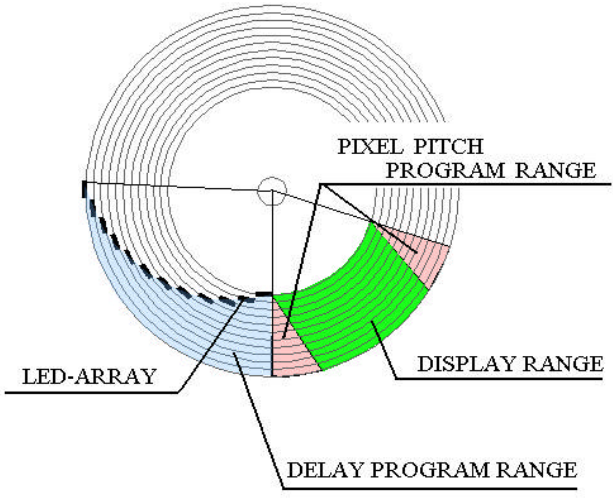



Fig.5 Program for display range correction

## 5. Display experiment

Table2 shows the specification of the three-dimensional display. As the experiment was made with the speed(R) of the turntable set at 480rpm. The number(n) of sets of 12-LED-arrays was two. The frame frequency (f) is determined according to the following formula in this case;

f (Hz) = [R (rpm)/60 (sec)]×n
= [480 (rpm)/60 (sec)]×2
= 16 (Hz)

Table 2 Specification of three-dimensional display

| | |
|---|---|
| Turn turntable speed (rpm) | 480 |
| Number of 3D image units<br>Images frame displays | 2 |
| Images frame displays (Hz) | 16 |
| Pixel pitch<br>[vertical V, horizontal H, depth D] | 5, 1.5, 7 |
| Number of pixel<br>[vertical V×horizontal H×depth D] | 16×48×12 |
| 3D image range*($mm^3$) | 76.5×70×77 |

* We measured the 3D image display's viewing angle in terms of its corresponding displayed rectangle.

## 6. Evaluation of viewing angle

Fig.6 shows the method of measuring the viewing angles of the three-dimensional images. The measurement was made from the most distinct points. Fig.7 shows the viewing angle for each point. The viewing angles obtained from the experiment result are as follows: 111.1-degree in right direction, 59.2-degree in left direction, 90-degree in upper direction, 41.0-degree in under direction. It was therefore confirmed that this three-dimensional display has a wide viewing angle.

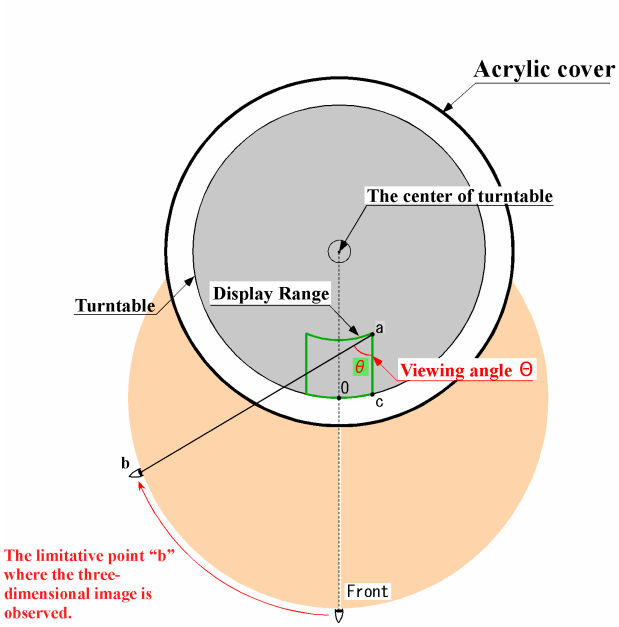



Fig.6 Viewing angle measuring method

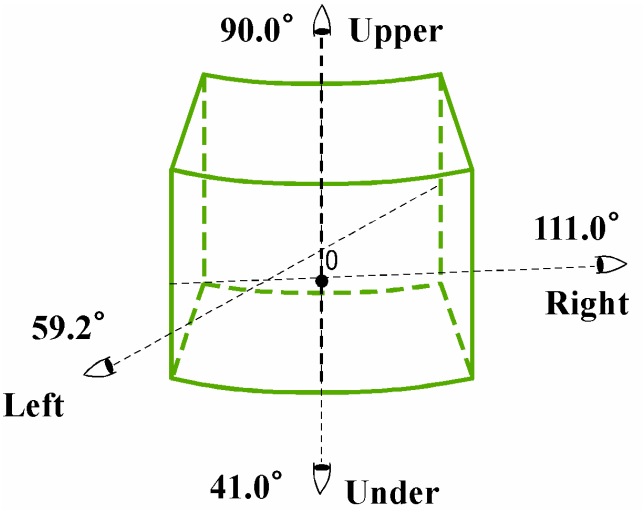



Fig.7 Viewing angles for each point

## 7. 3D image generation mechanism method

Fig. 8 shows the mechanism whereby the display system generates a 3D image. The system captures a 3D image divided into 12 sections in the depth-wise direction and combines them into its corresponding plane images with a vertical resolution of 16 picture elements, and a horizontal resolution of 48 picture elements.

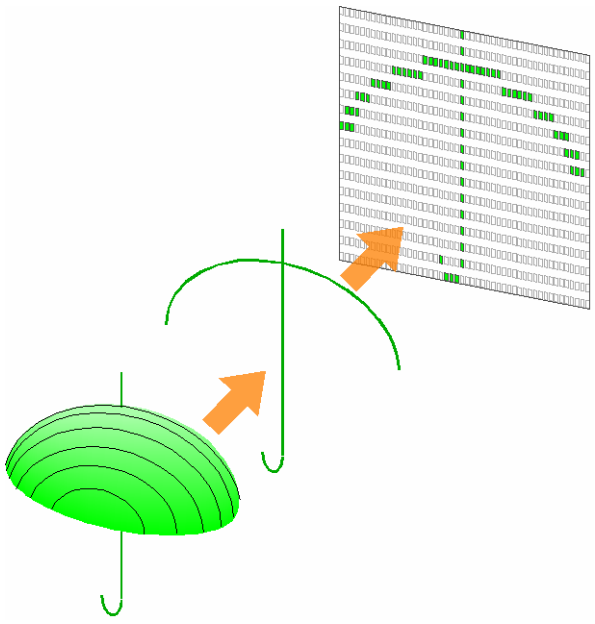


Fig.8 3D image generation mechanism method

Fig. 9 shows the captured 3D image of the umbrella.

Fig. 10 shows the actually displayed 3D image of the umbrella. When it is viewed from above, its convex portion can be observed. On the other hand, when it is viewed from below, its concave portion can be observed.

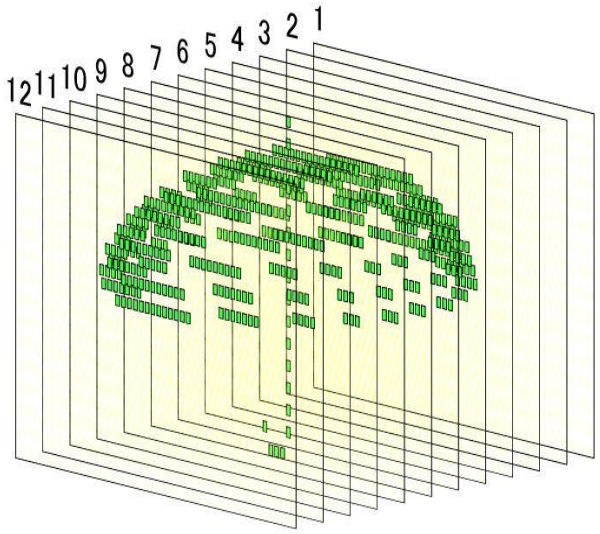



Fig.9 Captured 3D image of an umbrella

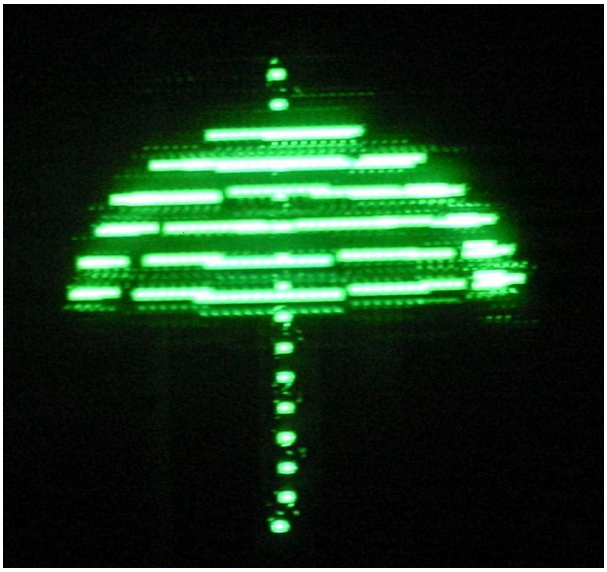


Fig.10 Actually displayed 3D image

## 8. Characteristics

The results of the experiment show that the display system has the following characteristics:

(1) Representation of three-dimensional images in real space;

(2) Wide viewing angle(in 360-degree horizontal, 70×2 degree vertical directions);

(3) High brightness;

(4) Only one LED required for the entire horizontal picture elements, resulting in sharp cost reduction; and

(5) Easy 3D animation display can be performed.(requiring only approximately eight frames).

## 9. Future consideration

For future consideration on the display system, we need to solve the following problems:

(1) Frame frequency;

(2) Resolution in the depth-wise and vertical direction;

(3) Color image display;

(4) Image display in real time; and

(5) Long-time 3D moving image display.

## 10. Conclusion

The turn type three-dimensional display system using LEDs has achieved three-dimensional image displays in real space, and has succeeded in displaying the three-dimensional moving image that depicts rain falling on an umbrella. This 3D display system has the function to automatically rotate the three-dimensional image 360-degree, allowing it to find application in 3D display for advertisement in lobbies of airports and stations, and other similar place.

## 11. References

[1] T. F. Budinger: An analysis of 3-D display strategies SPIE, Vol. 507,(1984).

[2] Y.Sakamoto, S.Maruyama, I.Fukuda: Proc. of IDW'02, 1257-1260.