Fresnel Arc 3D Display for Rewriting 3D Image with High-Pixel-Density Arrangement and Automatic Arc-Scratch Generation

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ABSTRACT

We proposed and developed a new Arc-3D-image rewriting method utilizing Fresnel arc structure with high-pixel-density arrangement and automatic generation of scratches. Fresnel Arc 3D display provides easy way of rewriting without arc-pixel selection difficulty. Proposed arrangement provides high-density pixels. Automatic generation of Arc-shaped scratch is realized by using cutting plotter.

1 Introduction

Long-viewing-distance large 3D display provides high impact to many viewers. Even in long-distance observation, interocular distance is fixed, so the number of viewpoints increase proportionately to observation distance. To solve this problem, some 3D displays have been proposed such as super-multi-view system [1] and 200-view 3D display using 200 high-definition projector units [2]. However, they have many multi-view images and difficulty in simple construction. On the other hand, Arc 3D display has simple structure composed of arc-shaped scratches [3-5], and smooth motion parallax both in horizontal and distance directions [6] can be achieved without huge number of multi-view images. This indicates that Arc 3D display is appropriate for long-viewing-distance large 3D display because it is no need to consider the interocular distance.

Although Arc 3D display has excellent advantages for long-viewing-distance large 3D display, it is hard to rewrite 3D image in Arc 3D display because arc-shaped scratches are difficult to rewrite. Seko et al. [7] proposed the simple rewriting method by selecting desired arc-shaped scratch, but it is difficult to select separately dense arc-shaped scratches.

In this paper, we propose a new rewriting method of Arc 3D image by utilizing Fresnel structure of arc-shaped scratch with high-pixel-density arrangement and automatic generation of scratches.

2 Principle of Arc 3D Display

Figure 1 shows principle of Arc 3D display. Arc 3D display is composed of many arc-shaped scratches which correspond to pixels in usual display. When arc-shaped scratches are illuminated by a single light, one bright spot appears to one eye. As left and right eyes observe different bright spots corresponding to interocular distance, binocular disparity leads to 3D image. Bright spot also moves on arc-shaped scratch smoothly according to one eye movement, resulting in smooth motion parallax.

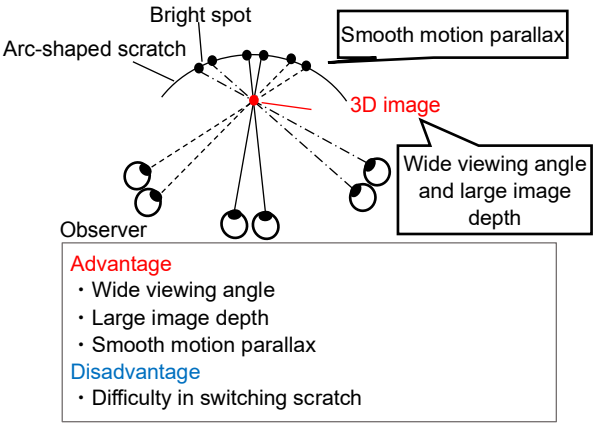


Fig. 1. Principle of Arc 3D display

3 Conventional Rewriting Method of Arc-Shaped Scratches

As one bright spot appears on one arc-shaped scratch to one eye by illuminating an arc-shaped scratch, one arc-shaped scratch corresponds to one ordinary pixel in usual display. However, in Arc 3D display, perceived depth depends on arc radius or illumination angle as shown in Fig. 2 [8]. Display structure composed of various arc radii is not practical because large number of arc-shaped structures with various radii are needed. On the other hand, it is practical to control the amount of perceived depth by adjusting the illumination angle without changing arc radius because only several illumination projectors are needed.

As shown in Fig. 3, Seko et al. reported rewriting method by arranging grid like array of arc shaped scratches and using illumination angle change [7]. This method allows to rewrite bright spot pattern and change the amount of perceived depth even if arc radius is fixed. However, this method has difficulty in selective lighting of desired arc-shaped scratch because crossing point of

adjacent scratches has very narrow gaps [7].

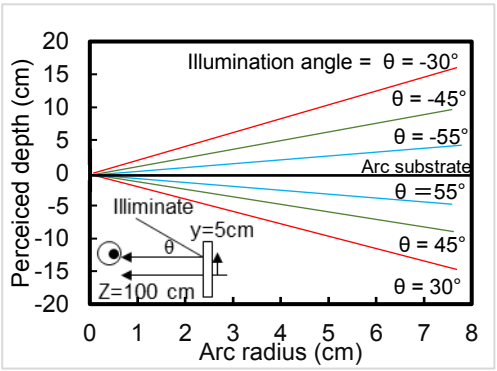
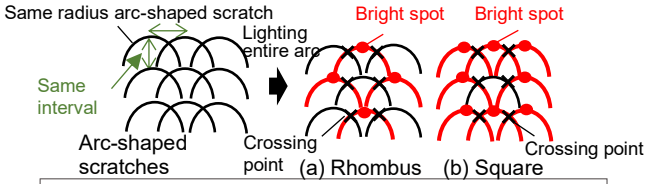


Fig. 2. Radius and illuminating angle dependency of depth (Yamada et al. [8]).



Advantage
- Changing bright spot pattern
- Changing the amount of depth by fixing arc radius or adjusting illumination angle

Disadvantage
- Difficulty in illuminating desire arc-shaped scratch because of crossing point

Fig. 3. Conventional rewriting arc 3D image method (Seko et al. [7]).

4 New Rewriting Method in Fresnel Arc 3D Display

To solve the crossing point problem with very narrow gaps in selecting desired arc-shaped scratch, we propose to use a Fresnel structure for the arc-shaped scratches in the arc 3D display [9]. As shown in Fig. 4, by dividing the arc-shaped scratches horizontally and shifting vertically, arc-shaped scratch can compress into compact-vertical rectangle region. By arranging these Fresnel arc-shaped scratches in a grid pattern, we can prevent the generation of cross point. This Fresnel arc-shaped scratch also increases the pixel density because the vertical direction is more compact than that of a conventional arc-shaped scratch. Moreover, as shown in Fig. 5(b), the bright spots move only in the natural horizontal direction according to the eye movement, unlike the circular arc-shaped scratch which has vertical parallax as shown in Fig. 5(a). An array of Fresnel arc-shaped scratch arranged in a grid without cross point is shown in Fig. 6.

First problem of proposed Fresnel structure is that, when the viewing zone is enlarged, the aspect ratio of rectangular pixels is increased, which is essential for 3D displays. The solution for this problem will be mentioned at next section 5. Second problem is that, as the Fresnel structure increases the number of scratches by a factor of ten or more, Fresnel structure provides the disadvantage of greatly increasing the workload. The solution for this problem will be mentioned at section 6.

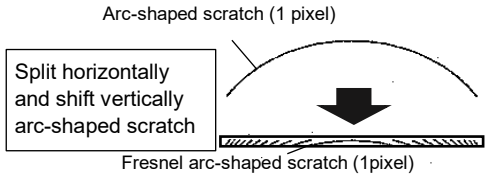


Fig. 4. Proposal of Fresnel arc-shaped scratch

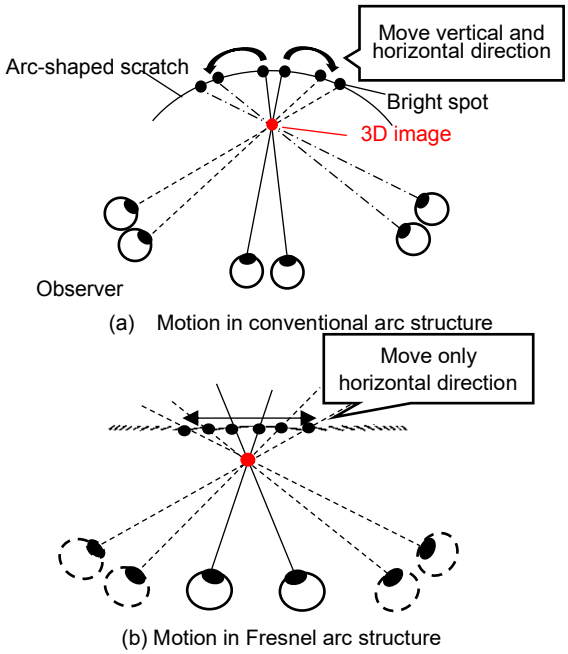
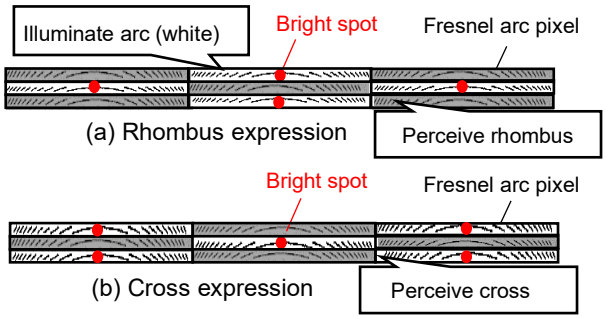


Fig. 5. Bright spot motion



- Compact vertically
- Move only horizontal direction
- No cross point
- Increase amount of arc

Fig. 6. Rewriting Fresnel arc pixels

5 Arranging Method to Increase Pixel Density

Although Fresnel structure has a problem of a large horizontal pixel size because of large viewing angle (Fig. 7), we propose the new pixel arrangement for the solution by shifting Fresnel arc pixel in horizontal direction and in vertical direction (Fig. 8). This arrangement provides high pixel density and makes horizontal pixel pitch almost the same as vertical pixel

pitch. Fresnel Arc 3D display constructed by this arrangement can provide a high resolution in horizontal and vertical direction despite horizontal large pixel (wide viewing angle).

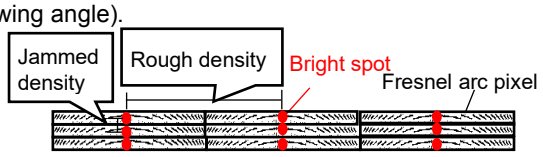


Fig. 7. Grid-like Fresnel Arc 3D

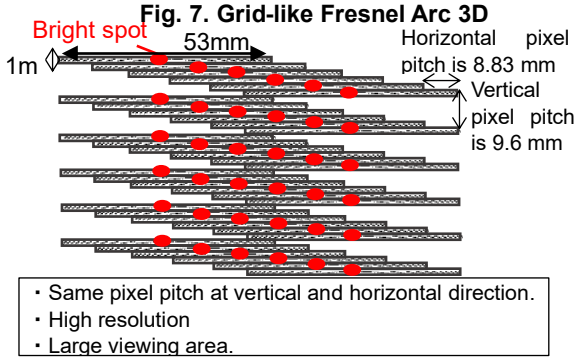


Fig. 8. New pixel arrangement in Fresnel arc

6 Automatic Generation of Arc-Shaped Scratch

If we make the Fresnel Arc 3D display, writing too many arc-shaped scrtches is needed. To solve this problem, automatic generation method of arc-shaped scratch is proposed by using cutting plotter. However, original brades supplied by cutting plotter are not appropriate for writing arc-shaped scratches. Figure 9 shows the bright spots of arc-shaped scratches written by these original brades. Arc-shaped scratches written by small edge-angle blades in (a) and (b) have expanded and low brightness bright spots. Blunter edge-angle blade in (c) has narrower bright spots but inadequate brightness and position deviation.

To obtain adequate bright spots, we propose to modify and reconstruct the new blades as shown in Fig. 10. A new piece of cutter blade with very sharp edge and wide width is attached to original blade for easy turn of cutting edge to scratch direction. Thus, the cutting edge can turn more easily to scratching direction, so it prevents unnecessary light scattering. As shown in Fig. 11, our restructured blade can make practical bright spot for Arc 3D display.

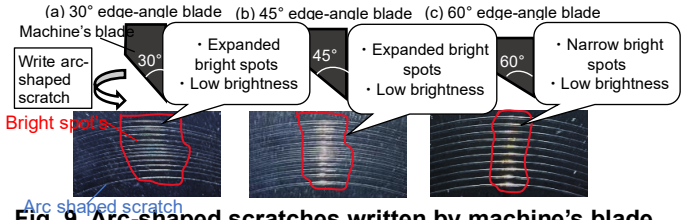


Fig. 9. Arc-shaped scratches written by machine's blade

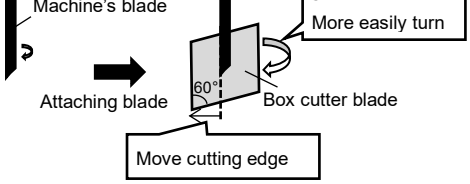


Fig. 10. Restructure machine's blade

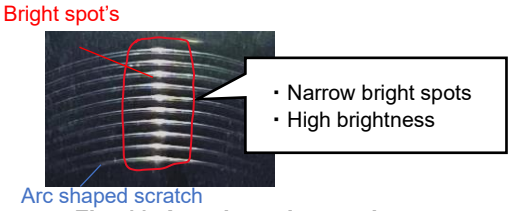


Fig. 11. Arc-shaped scratches written by proposed blade

7 Evaluation of Availability of Rewriting Fresnel Arc 3D Image

Availability of rewriting Arc 3D image was evaluated by using proposed Fresnel structure of 6×6 pixels. This 6×6 pixels arc-shaped scratches were made in about seven minutes by proposed generation method. One pixel was 1 mm vertically by 53 mm horizontally. Two patterns of all of them (36 pixel) and square shape (12 pixel) were evaluated.

Figure 12 shows the availability of rewriting Arc 3D image. Left and right-side photographs show illuminating patterns and perceived bright spot patterns. We can successfully select the desired arc-shaped scratches and obtain the desired bright spot patterns. These bright spot patterns make square image having the depth of 48 mm, and their horizontal viewing angle is as wide as 75 degrees.

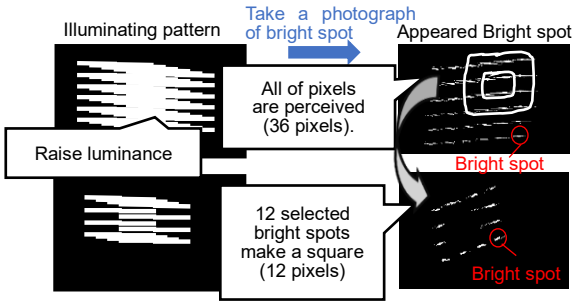


Fig. 12. Rewriting image by Fresnel arc-shaped scratch

8 Radius and Illumination Angle Dependency of Depth in Fresnel Arc

According to papers [6]-[8], it is expected that the depth is proportional to the arc radius and depends on the illumination angle. Radius and illumination angle dependency of bright spot's depth were evaluated in Fresnel Arc structure. Top and side view of experimental system and their photographs are as shown in Figs. 13 and 14. The arc radius was varied between 4 cm and 24 cm at 4 cm intervals. The interocular distance was 6.5 cm, the longitudinal observation position from the center of the arc was the same as arc radius, the depth observation distance from the center of the arc was 300 cm, and the light illumination angles θ = 30°, 40°, and 50° were used to evaluate depth.

As shown in Fig. 15, perceived depths are proportional to the arc radius. Although the measured value was larger than the theoretical value at the

illumination angle of 50°, the depth perception is almost the same as the theoretical value in conventional arc-shaped scratches.

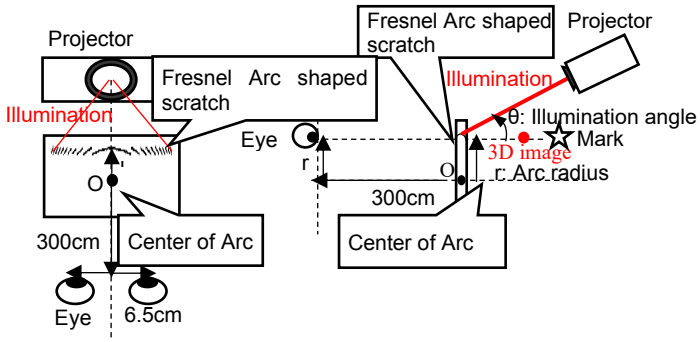
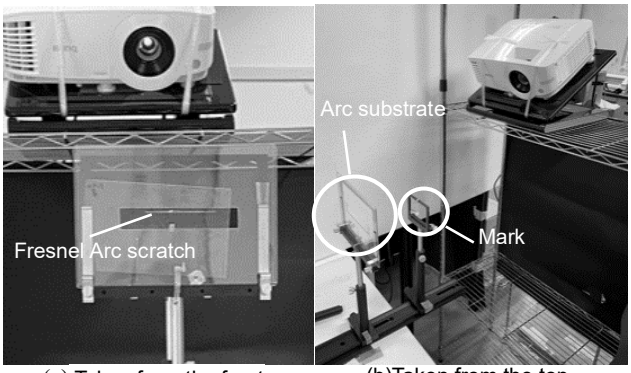


Fig.13. Top and side view of experimental



(a) Taken from the front (b)Taken from the top

Fig.14. Experiment system picture

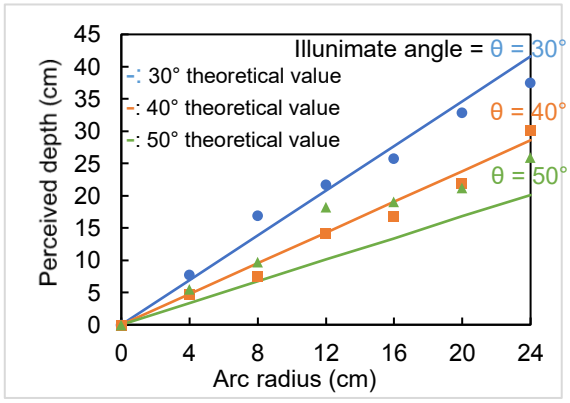


Fig. 15. Depth expression in Fresnel arc-shaped scratch

9 Conclusion

We propose and develop a new Arc-3D-image rewriting method, with high pixel-density arrangement and automatic generation method. Possibility of rewriting 3D image and depth perception are evaluated. Easy way of rewriting without cross point of arc-shaped scratches are provided by Fresnel arc structure. Proposed pixel arrangement method leads to high pixel density and horizontal pixel pitch almost the same as vertical pixel pitch. Automatic generation of arc-shaped scratch can be realized using a new proposed brade with cutting plotter.

Radius dependency of depth perception of Fresnel arc structure are almost the same as those in conventional arc-shaped scratches. Thus, our proposed Fresnel arc structure, new arranging method, and automatic generation method allow us to rewrite 3D image, and realize long-viewing-distance large 3D display.

Acknowledgement

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