Development of three-dimensional aerial image display system by integral photography

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ABSTRACT

Using developed integral photography (Hereinafter abbreviated as IP) in which a three-dimensional image display was possible, a three-dimensional aerial image was displayed by applying a double reflection micro mirror array (Hereinafter abbreviated as DRMMA). In this paper, we describe the experimental results on the visual perception characteristics related to the prototype three-dimensional aerial image.

1 INTRODUCTION

Generally, in aerial images, a two-dimensional image is often used as an image of a signal source. Therefore, the displayed aerial image is also a two-dimensional image display. In this paper, we described the results of a trial production of a device capable of displaying three-dimensional aerial images using DRMMA, using IP capable of three-dimensional image display as an image source, to carry out investigation on functions relating to visual functions.

2 Outline of the prototype

Figure 1 shows a prototype three-dimensional aerial image display. The display consists of LCD, convex lens array, and DRMMA (ASKA 3D plate, manufactured by Asuka Net). The IP image which is a three-dimensional image as a signal source is composed of an LCD and a convex lens array. The object is placed in the computer, and the multi-view stereoscopic image is generated, and in addition, it is obtained by pixel position conversion. The LCD has a size of 4.8 [inch], a resolution of 1920 × 1080 [dots], and a pixel pitch of 55.5 [μm]. The convex lens array has a lens pitch of 1 [mm] and a focal length of 3.2 [mm].

3 Characterization of the DRMMA

3.1 Measurement and results of luminance characteristics

From the reference position to the aerial image, the viewing position was moved at 5-degree intervals in the range of ± 20 ° in the horizontal direction and + 20 ° in the vertical direction, and the measurement was carried out in the position which was facing toward the display surface of the aerial image, as a standard. The imaging position of the aerial image was displayed 15 cm in front of the DRMMA plane. A luminance meter (LS -110, made by Konica Minolta) was used for luminance measurement.

Figure 2 shows the measurement results. From the measurement results, it was found that the larger the angle in both horizontal and vertical directions relative to the aerial image, the more remarkable the attenuation of luminance was observed. Additionally, there was no large difference in reducing the luminance level between the horizontal direction and the vertical direction.

3.2 Measurement and results of spatial frequency characteristics

A square wave pattern was displayed on the LCD, and the displayed aerial image was captured by high definition camera (D 800 E, made by Nikon), and the spatial frequency characteristic was obtained. The measurement range and the displaying position of the aerial image are the same as those in the measurement of luminance characteristics.

Figure 3 shows the measurement results. From the measurement results, the spatial frequency characteristics of aerial images decreased with increasing angle. It is shown that the decrease becomes large especially when the angle is 10 ° or more.

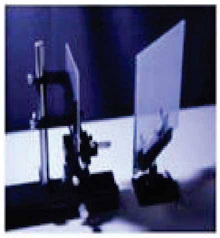


Fig. 1 Prototype three-dimensional aerial image display system

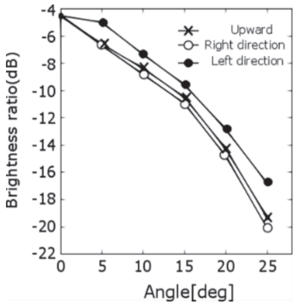


Fig. 2 Measurement results of luminance characteristics

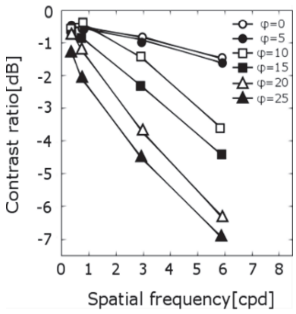
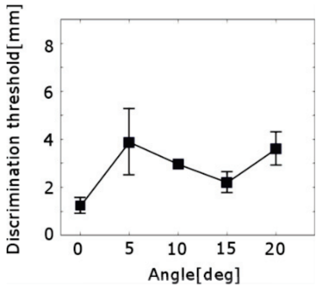


Fig. 3 Measurement results of spatial frequency characteristics

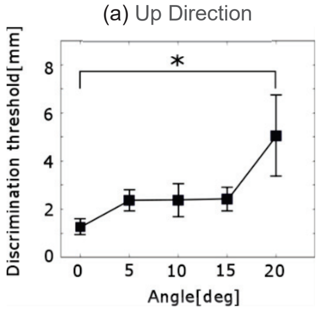
4 Evaluation of depth discrimination characteristics

4.1 Experimental equipment and subjects

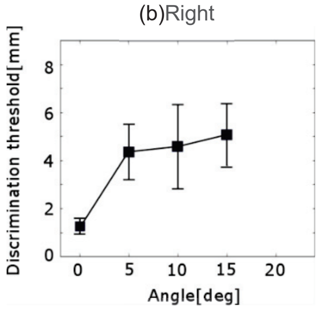
As the experimental equipment, the above described three-dimensional aerial image display was used. The



(a) Up Direction



(b)Right



(c) Left

Fig. 4 Evaluation results of depth discrimination characteristics

subjects were 3 males (21-23 years old).

4.2 Experimental method

From the reference position to the aerial image, the viewing position was moved every 5 degrees in the range of ± 20 ° in the horizontal direction and + 20 ° in the vertical direction, and the evaluation was carried out. The imaging position of the aerial image was displayed 15 cm before the center of DRMMA. In the evaluation, the plane patterns were displayed side by side, and the reference stimulus was presented on the left with the comparison stimulus presented on the right. In the experiment, the depth discrimination was evaluated by three-point scale using the method of limit, and the depth distance was changed by 6.4 [mm]. A total of 6 evaluations were performed. The difference threshold was determined by curve fitting using sigmoid function.

4.3 Measurement result

Figure 4 shows the measurement results. As a result of carrying out the multiple comparison for the obtained data, there was a significant difference at 1% between 0 ° and 20 ° on the horizontal right side.

5 Evaluation of depth reproduction range

5.1 Experimental equipment and subjects

As the experimental equipment, the above described three-dimensional aerial image display was used. The subjects were 6 males (21-23 years old).

5.2 Experimental methodt

The imaging position and display image of the aerial image are the same as in the evaluation of the depth discrimination characteristic. In the experiment, we used Scheffe's paired comparison method, and evaluated the depth discrimination using the five-point scale. The position of the reconstructed image was before and after 6.4 [mm] in the range of 79.7 [mm] to 41.3 [mm], and -60.9 [mm] to -99.3 [mm] (- Sign indicates far direction). A total of 12 evaluations were performed.

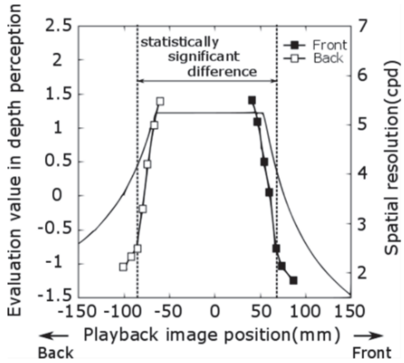


Fig. 5 Subjective evaluation result and spatial resolution at the reconstructed image position

5.3 Measurement result

Figure 5 shows the measurement results. As a result of the significance test for the evaluation result, the significance difference was recognized at 1% for each presentation position in the range of 66.9 [mm] in front of the display surface and 86.5 [mm] in the far direction.

6 Discussion

The maximum spatial resolution of the IP image used this time is approximately 5 [cpd]. The injection angle of the lens array used is 17.8 °, and 17.8 ° (approximately ± 9 °) is the viewing area of the IP image. According to the results obtained by the characteristic grasping experiment of DRMMA, the luminance level decreased by about 8 [dB] at the horizontal and vertical angles of ± 10 ° and the spatial resolution of 5 [cpd], and the spatial frequency characteristic decreased by about 5 [dB]. In addition, in the experimental result on the depth discrimination, the effect of the viewing position on the depth perception was recognized. However, there was no significant difference in the discrimination threshold in the range of 17.8 ° (approximately ± 9 °), which is the viewing area of the IP image used this time. Therefore, it is considered that the viewing area of the IP image can be applied to the prototype three-dimensional aerial image display device. In addition, the experimental results on the depth reproduction range showed a significant difference between the reproduced image positions within the range of 66.9 [mm] in the case where the reproduced image position is in front of the display surface after image formation and 86.5 [mm] in the case where the reproduced image position is in the back. Therefore, it is considered that depth discrimination is possible in the spatial resolution range of ± 4.1 [cpd] in this equipment.

7 Conclusions

Visual perception characteristics related to depth perception were examined in a prototype three-dimensional aerial image display device. In the future, the extension of the function as an interactive device and the reproducibility of the presentation position in displayed three-dimensional aerial images will be examined.