360 degree integral-floating 3D display with improved vertical viewing angle and image quality

Ganbat Baasantseren*, Nam Kim**, Munkh-Uchral Erdenebat**
*National University of Mongolia, Mongolia, **Chungbuk National University, Korea
E-mail : ganbatb@gmail.com*, namkim@chungbuk.ac.kr**, uchka@osp.chungbuk.ac.kr**

1. Background

Nowadays, the interest in the three-dimensional (3D) display is getting a lot, and so many papers published recently. Among the 3D display techniques, the integral imaging is the distinguished method to display full-parallax, full-color and continuous-viewing glasses-free 3D images; however it displays 3D images within narrow viewing angle and depth range. Several methods already conducted about the enhancement of viewing angle for the integral imaging, however those methods still provided in limited viewing angle. Moreover, the enhancement of any parameter affects to the others.

Recently proposed rotating screen-type volumetric light field display enables to display the 3D image in the 360 degree viewing zone that two-dimensional (2D) perspectives projected to each given viewpoint and the different images are observed in each eye, as similar with the stereoscopic 3D display [1]. Also, the vertically tracked camera system requires for the vertical parallax, because the display provides only in horizontal parallax.

Conventional 360 degree integral-floating display (IFD) which is the combination of the volumetric light field display and conventional IFD using double floating lenses fixes the problems of the both systems and combines the benefits also [2]. First of all, the elemental image arrays (EIA) are generated from the given angular viewpoints respectively, and uploaded to the memory of digital micromirror device (DMD) in the generated order. Then the DMD projects the EIAs by the order and a lens array reconstructs the 3D perspectives. Initial 3D perspectives are relayed to the mirror through the double floating lenses where the motor rotates the mirror in synchronization with the DMD projections. Here, the neighboring 3D perspectives are tailored in the horizontal direction on the rotating mirror, so the user observes the full-parallax 3D image in the 360 degree viewing zone. Moreover, due to using the 3D perspectives, very high frame rate of the projection doesn't require, and perfect depth cues of human visual perception is achieved. The demonstration was very effective; however the vertical viewing angle is quite low and the displayed image quality was not good enough.

2. Enhancements for the 360 degree IFD

For the vertical viewing angle enhancement, the anamorphic optics system (AOS) such as the vertically curved convex mirror is utilized instead of a flat mirror screen [3]. The AOS disperses the light rays more widely in the vertical direction, according to the mirror focal length. In the experiment, the vertical viewing angle is increased to approximately 50 degrees while it was only 4-6 degrees in the conventional 360 degree IFD, and it is possible to increase vertical viewing angle more, by controlling the focal length of the mirror. Figure 1(a) shows the schematic configuration of the display system and from the Fig. 1(b), enhanced vertical viewing angle can be presented.

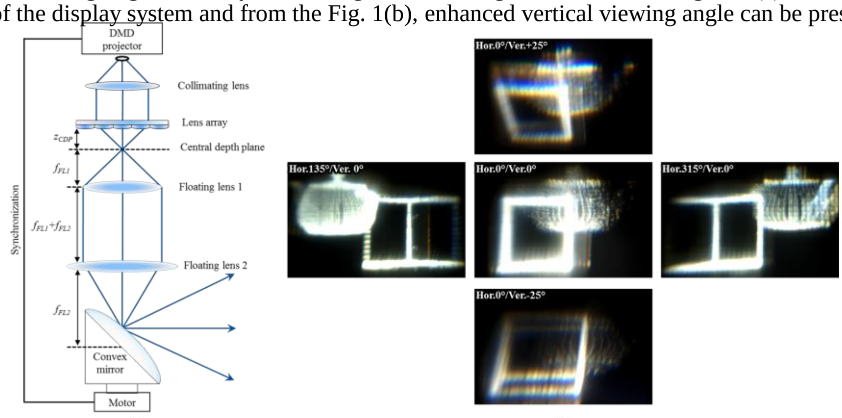

Figure 1. (a) Schematic configuration of the proposed display and (b) displayed 3D image with enhanced vertical viewing angle.

For the image quality improvement, a hexagonal lens array that each elemental lens is not rectangular, but hexagonal. Because the hexagonal lens array has a better fill factor due to hexagonal grid, so it gives a more accurate approximation of ideal circular lens and has more quantities of the elemental lenses. Moreover, the number of the point light sources which are created by each elemental lens is very important factor in the image quality: more number of the point light source is improves the displayed image quality. So, by use of the hexagonal lens array can improve the displayed 3D image quality [4].

The hidden point removal (HPR) operator requires also in the improvement of the displayed image quality. HPR operator determines the visible points of a point cloud model, from a given viewpoint, and demonstrates the 3D point cloud object in view-dependent reconstruction and in shadow casting [5]. In the proposed display system, the HPR operator determines the only corresponding visible points for each viewpoint. Then the EIAs are generated for each determined visible points of the point cloud object from the corresponding viewpoints, and the normal display processes are achieved.

In the experiment, a DMD projector (1024×768 micro-mirrors), double floating lenses (f_1=110mm and f_2=318mm respectively) and convex mirror (size=100×150mm and f_{CM}=87.65mm) are utilized.. The specifications of hexagonal lens array are similar with previously used rectangular lens array (f_{LA}=3mm and pitch=0.5mm). The object used in experiment is a virtual point cloud model of the teapot and cube. The system displays total 200 perspectives per round where an angular resolution is 1.8 degrees. The example of the displayed image on the AOS from multiple viewing directions for the corresponding EIAs is shown in Fig. 2. By the experimental result, we obtained the natural full-parallax omnidirectional 3D image with wide vertical viewing angle and enhanced viewing quality.

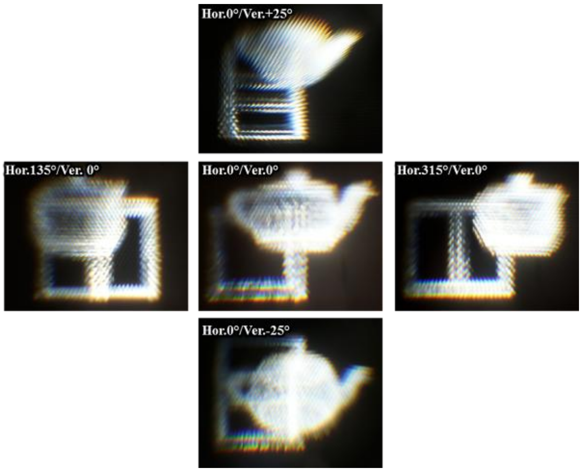

Figure 2. Displayed 3D image from the multiple viewpoint by using the EIAs which are generated for the hexagonal lens array and HPR operator.

This research was funded by the MSIP (Ministry of Science, ICT & Future Planning), Korea in the ICT R&D Program 2014.

3. References

[1] A. Jones, I. McDowall, H. Yamada, M. Bolas, and P. Debevec, "Rendering for an interactive 360° light field display", Proc. ACM SIGGRAPH, Vol. 26, Issue 3, Association for Computing Machinery, New York, United States of America, July 2007, pp. 1-10.

[2] M.-U. Erdenebat, G. Baasantseren, N. Kim, K.-C. Kwon, J. Byeon, K.-H. Yoo, and J.-H. Park, "Integral floating display with 360 degree horizontal viewing angle", J. Opt. Soc. Korea, Vol. 16, Issue 4, Optical Society of Korea, Seoul, South Korea, December 2012, pp. 365-371.

[3] M.-U. Erdenebat, K.-C. Kwon, K.-H. Yoo, H. Baasantseren, J.-H. Park, E.-S. Kim, and N. Kim, "Vertical viewing angle enhancement for the 360 degree integral-floating display using an anamorphic optic system", Opt. Lett. Vol. 39, Issue 8, The Optical Society, Washington D.C., United States of America, April 2014, pp. 17-27.

[4] N. Chen, J. Yeon, J.-H. Jung, J.-H. Park, and B. Lee, "Resolution comparison between integral-imaging-based hologram synthesis methods using rectangular and hexagonal lens arrays", Opt. Express, Vol. 19, Issue 27, The Optical Society, Washington D.C., United States of America, December 2011, pp. 26917-26927.

[5] S. Katz, A. Tal, and R. Basri, "Direct visibility of point sets", Proc. ACM SIGGRAPH, Vol. 26, Issue 3, Association for Computing Machinery, New York, United States of America, July 2007, pp. 24.1-24.10.