Computer-generated hologram synthesis for table-top holograhpic 3D display

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***Abstract*— Synthesis of polygon computer generated holograms for geometrically tilted optical imaging system is presented. Based on this, an efficient intermediate holographic view generation for efficient 360 deg. hologram content generation of table-top holographic 3D display is described.**

I. INTRODUCTION

Recently, research and development on 3D Holographic display is actively being undertaken. Computer-generated hologram (CGH) is one of the fundamental technology for holographic display and many computational issue is being discussed [1]. Above all, CGH representation has a huge importance in terms of the issues that determine how the holographic image may seem to the observer.

Table-top holographic 3D display as one of the CGH representation applications has a significant difference from a common holographic system. In contrast to the conventional holographic 3D display, in the case of the table-top system, observer's viewing direction is quite oblique, thus specialized content generation method should be employed.

There are several issues for observing the accurate image on the table-top system. Firstly, using the conventional method of generating the CGH contents, we face out the image distortion that is ascribed to the tilting geometry. Therefore, CGH algorithm for compensating the tilt distortion should be used to correct the reconstruction of CGH. Secondly, the enormous computation cost to calculate 360 deg. CGH content for the table-top holographic 3D display is a critical problem to overcome. Regarding this, we need to develop efficient algorithm for 360 deg. CGH. In this context, the efficient intermediate view generation algorithm should be devised.

In this paper, we will discuss several CGH issues in the aforementioned context. In Fig. 1, the table-top geometry under study is depicted. It is studied with numerical simulation what algorithm is appropriate for observing the correct image on the situation that the cube and checkerboard are located on z=0 (SLM plane) and z=-200mm (behind the SLM plane) respectively. The way to generate the CGH compensating distortions by using the angular spectrum representation and the effective method for calculating the CGH for the broad area with the intermediate synthesis algorithm are investigated for this geometry.

II. HOW TO CALCULATE A COMPENSATED CGH FOR TILTED PLANE

Unlike common 3D holographic systems, the retina plane is inclined relative to the SLM plane in the table-top holographic system, as shown in Fig1.

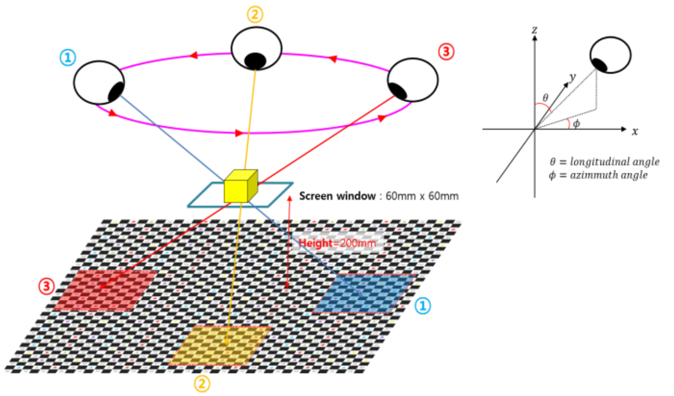

Figure 1. Table-top display system: geometry of the screen and observers

Thus the correct CGH cannot be obtained by the conventional method and we then implement the process that is composed of the following three steps for solving this problem.

1) Let the target holographic image on the retina plane convert to the temporary CGH on the virtual plane that is set up parallel to the retina plane and shares the center of mass with the SLM plane by the inverse Fresnel transform.

2) Then the temporary CGH on the virtual plane should be mapped to the original SLM plane which we want to obtain. After setting the SLM plane and the virtual plane in the global and local coordinate systems, respectively, represent the light field distribution in the virtual plane by the angular spectrum representation. According to the relation of the rotating transformation between the global and local coordinate systems, translate the local angular spectrum representation into the form of the global angular spectrum representation.

3) We should note that the light field distribution obtained through a series of the above processes is represented in a high frequency region due to an oblique carrier wave. For the hologram image reproduction in a simulation or a practical experiment, we need just a signal profile containing the information of the image. For that reason, a signal profile located at a high frequency region can be separated from the

carrier frequency, and then shifted to a low frequency region with the elimination of the carrier wave. In accordance with 1), 2), 3) steps, we can find out the mapped CGH distribution on the SLM plane finally. The following simulation results show the compensated CGH and the hologram image for the situation that the observer is situated around the display

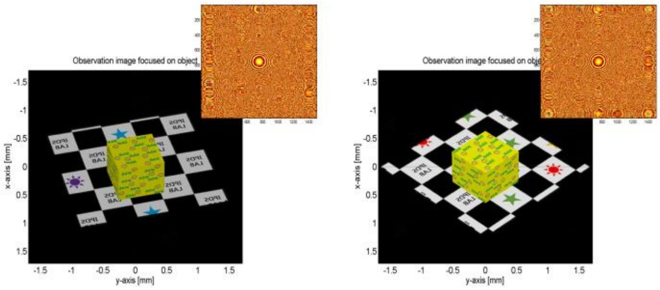

Figure 2. Numerical reconstruction results of table-top CGHs

III. INTERMEDITATE CGH VIEW GENERATION ALGORITHM

An observer going around the table-top display can perceive the natural 360 deg. hologram image if the different parallax CGHs for all the directions are prepared in advance. However, this procedure is not effective because it requires a great amount of computation complexity and data. Intermediate synthesis algorithm is a computational algorithm of adaptively updating CGHs of mesh 3D objects for the positional change of an observer with low computational load by efficiently using pre-calculated elementary CGH.

Here, the intermediate CGH view generation algorithm using the reconfiguration algorithm [2] is briefly described. When the observer is situated at a particular position, a triangle facet comprising the hologram image is assumed to be represented as the form of the windowed angular spectrum, where the center of window is determined by the observer's position

$$W_i(x,y,z) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \Gamma(\alpha-\alpha_k,\beta-\beta_k)A_{G,K}(\alpha,\beta)\exp\left[j2\pi(ax+by+gz)\right]d\alpha d\beta. \quad (1)$$

When the observer's viewing position is changed and the carrier wave vector $(\alpha_k,\beta_k,\gamma_k)$ is changed to $(\alpha_k+\Delta\alpha,\beta_k+\Delta\beta,\gamma_k+\Delta\gamma)$ due to a spatial movement of the observer, the reconfigured angular spectrum of the triangular facet, $\bar{A}_{G,K}$, can be obtained as the simply modified form as

$$\begin{aligned}&\bar{A}_{G,K}(\alpha,\beta)\\&= cA_{G,K}(\alpha-\Delta\alpha,\beta-\Delta\beta)\exp\left(-j2\pi\left(\Delta x(\alpha-\Delta\alpha)+\Delta y(\beta-\Delta\beta)\right)\right).\end{aligned} \quad (2)$$

where c is a constant term, $\exp(-j2\pi(\alpha_k\Delta\alpha+\beta_k\Delta\beta))$. Through the above reconfiguration procedure, the whole computation is expected to be more efficient than a way of totally re-computing the CGHs. We will discuss about the minimized number of CGHs for the 360(deg) view in according to the positional change of an observer.

IV. CONCLUSION

We have described the method for generating the CGH which compensates the distortion caused by an observer located the slope from the table. In addition, we have suggested a way of effectively calculating the CGH for the 360 deg. broad viewing area by applying the intermediate synthesis algorithm to table-top 3D display system.

ACKNOWLEDGMENT

This work was supported by GigaKOREA project, [GK13D0100, Development of Telecommunications Terminal with Digital Holographic Table-top Display].

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