Synthesis and analysis of depth-map computer generated holograms

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***Abstract*—Synthesis and analysis of computer generated hologram (CGH) based on the depth map image data are studied. Through this, the image defects induced by the phase discontinuity and diffraction between the inter-layers of depth-map object model are observed and the synthesis method to overcome these defect is addressed. A key approach in the proposed method is the preprocessing step of shaping the carrier wave which is a light field delivering the information of the holographic image to observer's viewing window.**

Keywords—depth map; computer generated hologram, diffraction

I. INTRODUCTION

Digital holographic three-dimensional (3D) display is considered as ultimate 3D display and widely researched. Until now, in the commercial field of 3D displays, stereoscopic 3D display has been captured high portion. However, for more realistic and fatigue-free 3D displays, it is essential to generate holograms which reproduce the optical wave field representing 3D object. There are several advantages of holographic 3D display in comparison with stereoscopic display. One is the accommodation effect of holographic 3D display, which means that there is no conflict regarding to the discordance between binocular and monocular parallaxes.

A great deal of technology development associated with hologram has been proceeded to realize commercial holographic 3D displays. One cue to develop new technique for holographic 3D display based on the former techniques of 2D displays. The intersection of these techniques is worthwhile to consider. One example is the computer generated hologram (CGH) synthesis that is based on depth map. The depth map is the 3D image format which contains the light intensity profile and the information of the distance of the surfaces of scene object from an observation point. The depth-map is widely used in computer graphics.

In this paper, we deal with the generation of the depth-map CGH. The conventional depth-map CGH method raises some considerable defects in the scene of hologram on the borders of respective depth layers. The distance information in depth map is usually quantized so that the phase mismatch and inter-layer diffraction between the adjacent layers won't be significant to degrade image quality.

According to Sommerfeld's theory of half-plane diffraction, the diffraction occurs on the boundaries of depth layers. These cause blurring effect in the holographic scene. The inter-layer diffraction from the edge of the boundary between depths could be reduced by making the depth interval shorter in general sense, but the computation of CGH will increase with the number of layers.

In this paper, the defect problem in the depth-map CGH is analyzed and the novel synthesis method without defect in limitative number of layer is proposed.

II. ANALYSIS OF IMAGE DEGRADATION IN DEPTH-MAP CGH

In this section, the defect from the phase-mismatch and the inter-layer diffraction of optical wave is analyzed. Figure 1 illustrates the numerical observation results of the depth-map CGH with various number of depth level for a simple 3D object. A line defect on the layer boundaries are perceived certainly in the case that the number of layers is two. As the number of quantized depth increases and the inter-layer interval gets shorter, the boundary defects tend to be reduced, which is illustrated in Fig. 1. Even though the effect of the interlayer diffraction is decreased in the case of twenty layers, the holographic image seems to still be unclear, which is thought to be ascribed to the phase discontinuity at the layer boundaries.

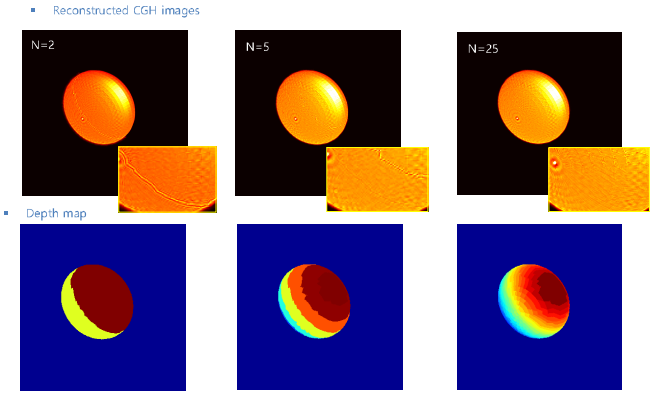

Figure 1. Observation results of the depth-map CGH with various number of depth level

Let us consider the direct view type holographic display and its carrier wave which is a waveform conveying the modulated holographic wave field to the viewing window.

With the trapezoidal depth-map mode, the carrier wave propagates from the layers in the depth-map object to the viewing window. The important note is that to generate clear hologram image, the carrier wave should reserve its regularity

or continuity in its wave front. However, in the quantized structure of the depth layers, considerable image contamination can be caused by the phase mismatch among the partial carrier wave coming from each layer and the inter-layer diffraction. Figure 2 presents the carrier wave pattern designed for a trapezoidal depth-map structure. For simplicity, a simple parabolic curved surface is taken as the target object. Interferometric defects are observed in the field distribution. In this case, the inter-layer diffraction generated by sharp edges of the depth-map layers occurs and results in contamination in the carrier wave pattern.

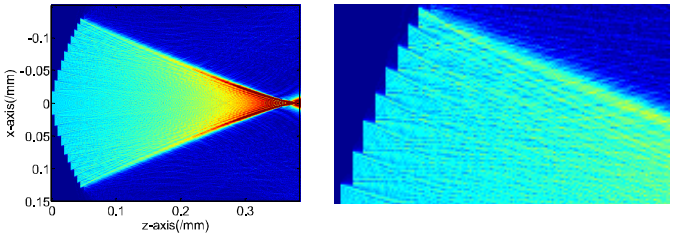

Figure 2. Carrier wave pattern for the trapezoidal depth-map model

To reduce the effect of the inter-layer diffraction, the depth interval should be taken as small as possible, but as the number of layers increases, computational cost becomes tremendous.

III. SYNTHESIS OF DEPTH-MAP CGH WITH HOLOGRAPHIC CARREIR WAVE

In this section, a novel approach is proposed for overcoming the defect problem of the conventional trapezoidal depth-map CGH. The key approach is to use holographically synthesized carrier wave without wave front irregularity.

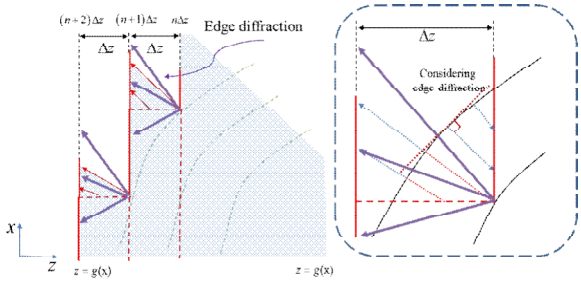

Figure 3. Concept of holographicalyy synthesized carreir wave for depth-map CGH

To obtain the holographic carrier wave, we need to backwardly propagate the well-defined converging carrier wave toward to the trapezoidal layer structure and record the complex optical field distributions on the layers of the depth-map structure. Figure 4 illustrate the forward propagation of the holographically synthesized carrier wave. It is seen that the interferometric defects in the carrier wave field pattern vanishes successfully in contrast to that in Fig. 4.

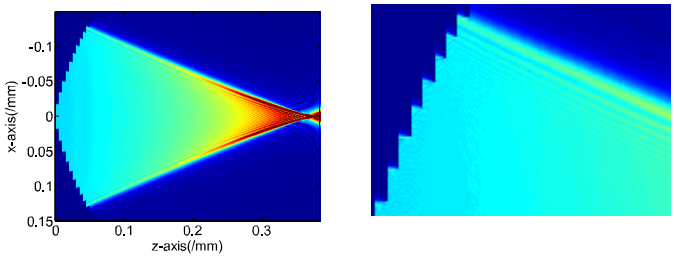

Figure 4. Holographically synthesized carrier wave pattern for the trapezoidal depth-map model

Based on the novel technique of holographic carrier wave, we will continue to develop photorealistic depth-map CGHs and report the progress in this study.

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