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Hybrid Technique of Polygon-Based and Ray-Sampling Plane-Based methods in Full-Parallax High-Definition Computer Holography

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Abstract: Reconstructing photorealistic 3D images of deep objects is still challenging for full-parallax large-scale computer-generated holograms. To address this problem, we propose a hybrid technique based on physical simulation and multi-viewpoint images.

1. Introduction

Several techniques have been proposed for calculating computer-generated hologram (CGH). One of the common techniques is polygon-based method [1]. Recently, many full-parallax high-definition CGHs (FPHD-CGH), composed of several tens billion or sometimes a hundred billion pixels, have been created using the polygon-based method [2]. The 3D images of these FPHD-CGHs are very impressive because they reconstruct very deep 3D scene without any conflicts of depth sensation.

In the polygon-based method, the object wave is calculated from planar surface light sources that have polygonal shapes. Since this technique is based on physically simulation, all depth cues in human perception can be satisfied naturally. However, advanced rendering techniques established in computer graphics (CG), such as refraction and anisotropic reflection, have not been developed in this method. On the other hand, the method based on ray-sampling plane (RSP) can deal with this problem [3]. In this approach, the RSP is defined near the object, and the object ray is sampled from multi-viewpoint images (MVI) in the RSP. The sampled ray is converted into the object wave by Fourier transform. Hence, advanced rendering techniques used in CG can be directly applied for calculating object waves. However, this method is not suitable for deep objects, whose shape spreads in the depth direction, because the object wave is obtained from MVI without any depth information.

In this paper, we propose a hybrid technique of the polygon-based and RSP-based methods to reconstruct deep photorealistic 3D images by FPHD-CGHs.

2. Principle of the proposed technique

Figure 1 shows the 3D scene used for creating a FPHD-CGH. Only the yellow toy train is calculated using the RSP-based method, while the gray parts of the model, i.e., other than the yellow part are calculated using the polygon-based method. Here, note that the gray and yellow toy trains partially hide each other. Thus, we must deal with the complicated mutual occlusion over two different methods.

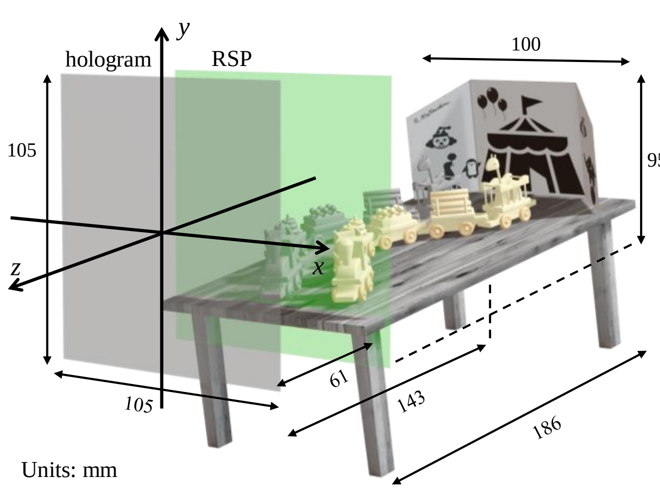

Fig. 1. The 3D scene of the created FPHD-CGH.

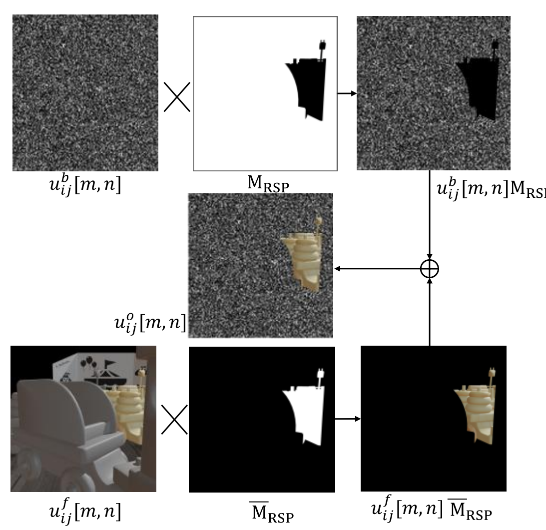

Fig. 2. Occlusion processing in a segment of the RSP.

The proposed technique consists of three steps. In the first step, the object wave behind the RSP is generated by the polygon-based method, then it is numerically propagated to the RSP. Next, the object wave is obtained using the RSP-based method. Here, in the proposed method, the occlusion processing is performed by a procedure based on ray-wavefront conversion technique [4].

Figure 2 shows the occlusion processing for one of the MVI in the RSP. Let $u^b[m,n]$ denote the converted ray information from the background wavefield calculated by the polygon-based method and $u^f[m,n]$ denotes the rendering image by CG, where *m* and *n* represent sample points in the given MVI. $\mathrm{M_{RSP}}$ is the binary mask whose value is 0 in the region including the objects processed by the RSP-based method. $\overline{\mathrm{M}}_{\mathrm{RSP}}$ is an inverted binary mask of $\mathrm{M_{RSP}}$. In the proposed technique, the ray information is obtained by the following mutual masking:

$$u^o[m,n] = u^b[m,n]\mathrm{M_{RSP}} + u^f[m,n]\overline{\mathrm{M}}_{\mathrm{RSP}} \tag{1}$$

Finally, the object wave in the front side of the RSP is calculated using the polygon-based method again. Note that occlusion processing in the polygon-based method is performed by the switch-back technique [5].

3. Creation of FPHD-CGH

Optical reconstruction of the FPHD-CGH, created using the proposed technique, is shown in Fig. 3. The CGH is composed of 128K × 256K pixels where 1K = 1024; the total pixel number exceeds 34 billion. The horizontal pixel pitch is 0.8 μm, while vertical one is 0.4 μm to avoid non-diffraction and conjugate light using the fringe-oversampling technique [6]. The reconstruction wavelength is 630 nm. The RSP is composed of 256 × 256 segments; each segment has 512 × 512 pixels. Figure 3 confirms that the created FPHD-CGH reconstructs appropriate occlusion and motion parallax in both the horizonal and vertical directions.

4. Conclusion

In this paper, we proposed a hybrid technique based on the polygon-based and RSP-based methods, and created a FPHD-CGH. It is verified by the optical reconstruction that the proposed technique seamlessly combines the 3D images produced by two methods.

5. References

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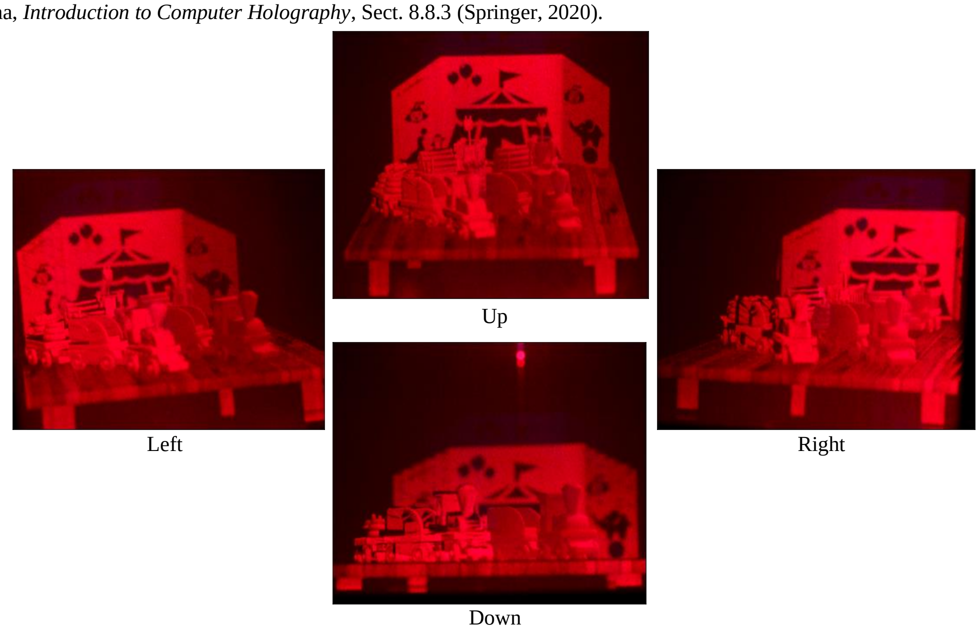

Fig. 3. Optical reconstruction of the FPHD-CGH created using the proposed technique.