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A High-Definition Full-Parallax CGH Created by the Polygon-Based Method

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Abstract: A large-scaled full-parallax CGH with 4 billion pixels is produced by a polygon-based method. The CGH reconstructs a fine 3-D image and gives a large sensation of depth owing to the silhouette-masking technique.

OCIS codes: (090.1760) Computer holography; (090.2870) Holographic display

1. Introduction

The technology of computer-generated holograms (CGH) has a long history. The technology is the counterpart of computer graphics in 2D images and sometimes expressed as an ideal 3D technology. However, CGHs were just the subject of academic research and could not produce yet fine 3D images with a large sensation of depth.

Such fine CGHs commonly require a large viewing-zone and image size. Both of them lead to a large pixel size. However, conventional "ray-oriented" point-based methods are much time-consuming especially in full-parallax and hidden-surface-removed CGHs. Therefore, it is not easy to produce such fine CGHs by the point-based methods.

One of the authors has proposed "wave-field oriented" polygon-based method [1] to get over the limits of the point-based methods. In this new technique, the object is composed of some polygonal facets; polygons. Each polygon is regarded as a surface light source and the object field is computed by totaling the light from polygons. Several researchers have also proposed improving our method to compute faster at the sacrifice of texture mapping and uniform diffusiveness [2,3].

Occlusion is one of the most important mechanisms in the perception of 3D scenes. To add an effect of mutual occlusion to the reconstructed 3D scene in CGHs, light shielding by obstacles must be realized in calculating object fields. This is also one of weak subjects of point-based methods. Since numerical propagation of wave fields is used in polygon-based methods, such light shielding is simply achieved by the silhouette masking technique [4].

This investigation is intended to produce CGHs reconstructing truly fine 3D images by combination of these new techniques and fabrication using laser lithography system.

2. Setup of 3D scene of "The Venus" CGH

The CGH created is named "The Venus" because the object given by a set of mesh data is similar to the famous statue of the Venus of Milo. In addition, wallpaper that is a binary check pattern is placed behind the Venus statue to enhance observer's sensation of depth. Geometry and dimensions of the objects are shown in Fig. 1. Some detailed parameters of the hologram and objects are summarized in Table 1.

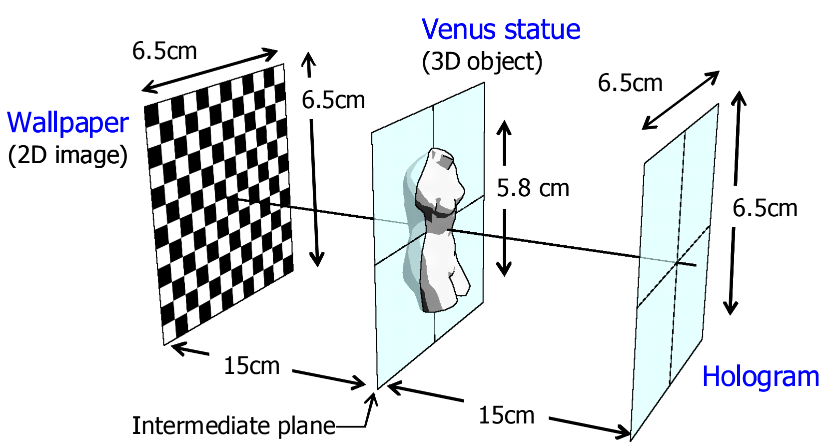

Fig. 1. Schematic geometry of "The Venus" CGH.

Table 1. Parameters used for creation of the CGH

Hologram	
Pixel sizes	65,536 × 65,536 pixels
Pixel pitches	1 μm × 1 μm
Hologram type	Binary amplitude
Reconstruction wavelength	632.8 nm
Venus stature	
Number of visible polygons (front-face only)	718
Dimensions (W × H × D)	26.7 × 57.8 × 21.8 mm^3
Wallpaper	
Pixel sizes of texture image	256 × 256 pixels
Dimensions (W × H)	65.5 × 65.5 mm^2

3. The polygon method for calculating the field of the 3D object

The polygon method used for calculating the wave field of the Venus object is summarized in Fig. 2, where a cubic object shown in (a) is used as an example. The surface function for the polygon #2, defined in the local coordinates peculiar to the polygon #2, is shown in (b). The amplitude and phase distribution give the shape and diffusiveness of the polygon, respectively. The surface function is transformed into the wave field in the global coordinates $(\hat{x}, \hat{y}, \hat{z})$, in which the hologram is placed in $(\hat{x}, \hat{y}, 0)$ plane, by using the rotational transformation [5] and spectrum remapping [1]. Here, the transformation matrices between the local and global coordinates are obtained by the Rodrigues' rotation formula.

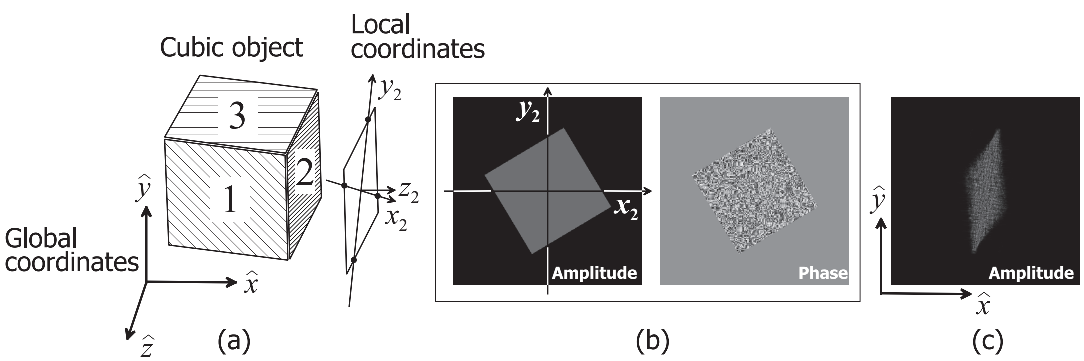

Fig.2. A summary of the polygon method: (a) an object model, (b) the surface function of the polygon #2 in the local coordinates, (c) the amplitude image of the resultant wave field in global coordinates.

The wave field of the 3D object is obtained in an intermediate plane by totaling fields of all polygons of the 3D object. The intermediated plane is parallel to the hologram and slices the object at the center as shown in Fig. 1. There are two reasons why the object field is temporally calculated in the intermediate plane. First, calculating the object field in the intermediate plane is faster than doing in the hologram plane, because the polygons are closer to the intermediate plane than the hologram one. Since polygon fields are not diffracted so much in the intermediate plane, the area for calculating the polygon field is much smaller than that in hologram plane. Secondly, light shielding of the wallpaper field is necessary for avoiding phantom image of the 3D object, as explained in the following section.

4. Generating the wallpaper field and its shielding by the silhouette masking technique

Since wallpaper is parallel to the hologram, the wave field is simply generated by multiplying oversampled and pixel-increased texture image by a diffuser phase. The generated field should be numerically propagated to the hologram plane. However, if the wallpaper field is simply propagated and added to the field of the 3D object, the 3D object would be reconstructed as a phantom image, because simple superposition involves light transmission of the 3D object. To shield wallpaper behind the 3D object, the

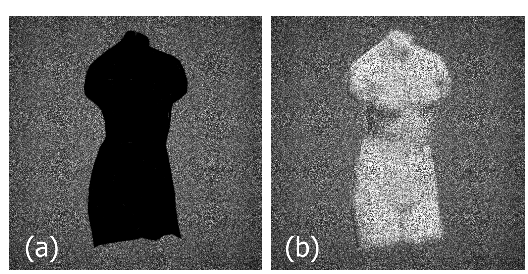

Fig. 3. The masked wave field of wallpaper (a) and the combined wave field (b) in the intermediate plane.

propagation process should be divided into two steps. The wallpaper field is first propagated to the intermediated plane in which the field of the 3D object is obtained and then masked with the silhouette of the 3D object, as shown in Fig. 3 (a). After the 3D object field is superimposed on the masked wallpaper field as in (b), the combined field is finally propagated to the hologram plane.

5. Computation and fabrication

The CGH was calculated by using a PC with 4 CPU of AMD Opteron 852 (2.6GHz) and 32 G Bytes RAM. Total computation time was approximately 45 hours. Longest time was consumed in a double numerical propagation. The amount of computation time for propagation was 37 hours and accounted for 82% of total computation time, while time for producing the 3D object field was 7.6 hours. The CGH was fabricated by DWL 66 laser lithography system made by Heidelberg Instruments, GmbH.

6. Optical reconstruction and conclusion

We created a high-definition full-parallax CGH of 3D object by using the polygon-based method and the silhouette masking technique. Photographs of its optical reconstruction, taken from various camera angles, are shown in Fig. 4. The 3D surface object with shade is clearly reconstructed and occludes light from wallpaper. As a result, the produced CGH gives a strong sensation of depth and reconstructs the fine 3D image.

7. Acknowledgement

The mesh data of the Venus object is provided courtesy of INRIA by the AIM@SHAPE Shape Repository.

8. References

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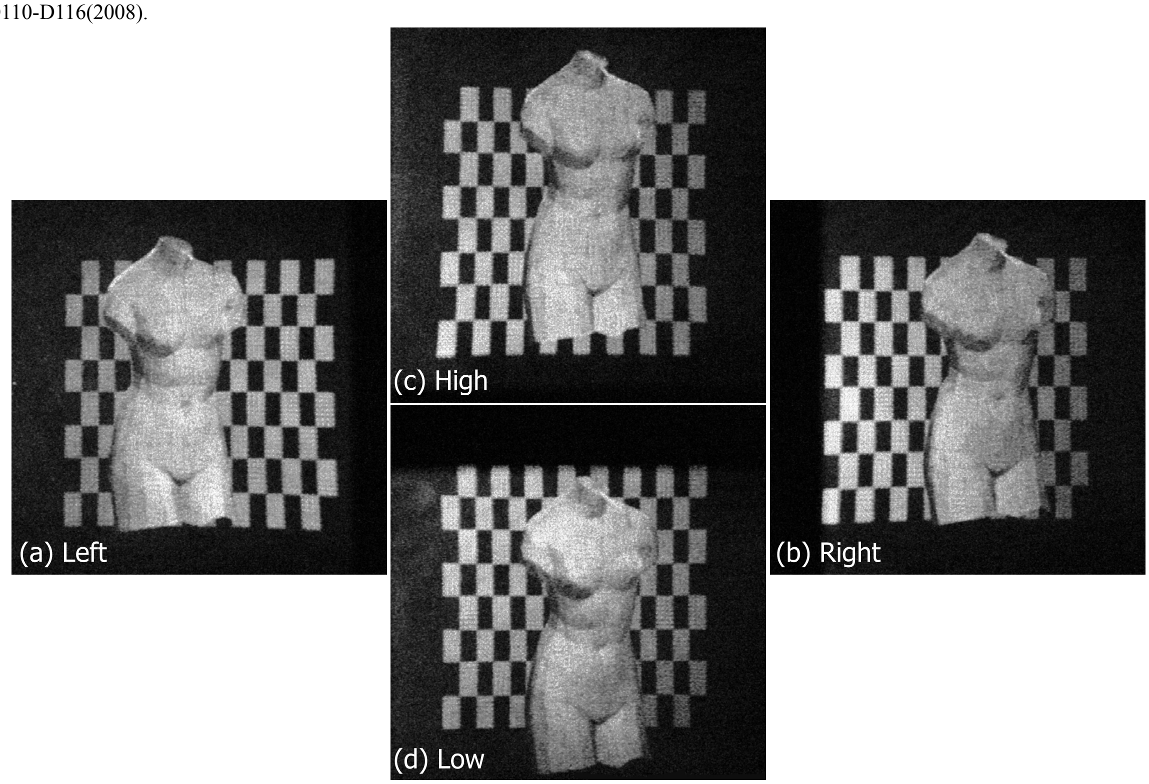

Fig. 4. Photographs of optical reconstruction of "The Venus" CGH.