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Recent Techniques for Hidden Surface Removal in Computer Holography

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Abstract: Some techniques recently introduced into high-definition computer holography are reviewed. A new method called switch-back technique plays an important role to accelerate computation of the conventional silhouette masking and more accurate polygon masking. A new technique for light-shielding in digitized holography is additionally presented for reducing occlusion errors.

OCIS codes: (090.1760) Computer holography; (090.2870) Holographic display; (090.1995) Digital holography

1. Introduction

High-definition computer holography based on wave optics has been developed for a past few years [1-4]. This technology allows us to create high-definition computer-generated holograms (CGH) composed more than billion pixels, whose optical reconstruction is comparable to that in conventional optical holography. These high-definition CGHs give viewers strong sensation of depth that has never been achieved by stereoscopic 3D (S3D) images, because the CGHs reconstruct spatial images accompanied with all depth cues.

Occlusion of scenes and objects is one of the most important depth cues in computer holography as well as S3D images. However hidden surface removal necessary for reconstructing occlusion is also one of the most difficult subjects in computer holography. In point-based methods, commonly used for calculating object fields, hidden surface removal is realized by removing rays blocked by obstacles. This is, however, very time-consuming and thus an impractical method especially in high-definition computer holography. Instead of this kind of approaches silhouette-masking techniques have been proposed in polygon-based methods [5,6]. In this technique, wave-fields instead of rays are blocked by silhouette-shaped masks of the obstacles. This is the technique based on wave optics, and therefore, best fits with polygon-based methods that are also based on wave optics.

Initially, the silhouette-masking technique was proposed for shielding light behind polygons. However, the polygon-by-polygon silhouette masking was too time-consuming to apply it to high-definition CGHs. Thus, masking by the object silhouette was instead used for creating high-definition CGHs [1]. The object-by-object silhouette masking is definitely faster than the polygon-by-polygon technique, but does not work well if the object has severe self-occlusions. To get over the problem, we present a new technique called the switch-back technique [7]. This technique makes it possible to speed up polygon-by-polygon masking and apply it to high-definition CGHs.

More accurate light-shielding technique than the silhouette method that is coarse light-shielding in a sense is also discussed and presented. The technique itself has been proposed [8] but never been applied to high-definition CGHs because of its long computation time. Light shielding in digitized holography is another topic in computer holography. In digitized holography, the object field in a wide area is digitally captured by synthetic aperture digital holography at high density [9]. In this case, the shape of the object necessary for producing masks must be estimated from the captured fields.

2. Conventional silhouette method and its acceleration by switch-back technique

Figures 1 shows the conventional silhouette method. The procedure is expressed by a recurrence formula:

$$u_{m+1}(x,y) = \mathbf{P}_{m+1,m}\left\{M_m(x,y)u_m(x,y) + O_m(x,y)\right\}, \tag{1}$$

where $u_m(x,y)$ is the wave-field in the plane (x, y, z_m) behind polygon m, and $M_m(x,y)$ and $O_m(x,y)$ are the silhouette-shaped mask function and object field also given in the plane (x, y, z_m). Here, polygons are numbered in order of depth and the deepest has $m = 0$. The symbol $\mathbf{P}_{m+1,m}$ stands for numerical propagation of the field from the plane at z_m to z_{m+1} in the whole cross section of the 3D scene. The propagation is required M times for processing an object composed of M pieces of polygons. This is very time-consuming for high-definition CGHs.

The following recurrence formulas are also derived from Eq.(1) by some steps.

$$u_{m+1}^H(x,y) = u_m^H(x,y) + \mathbf{P}_{H,m}\left\{O_m(x,y) + A_m(x,y)u_m(x,y)\right\}, \tag{2}$$

$$u_{m+1}(x,y) = \mathbf{P}_{m+1,H}\left\{u_{m+1}^H(x,y)\right\}, \tag{3}$$

where $A_m(x,y) = 1 - M_m(x,y)$ is the aperture function and $u_m^H(x,y)$ is the sub-total field in the object plane defined near the object, which accumulate the field from the deepest to polygon m–1. Here, the symbols $\mathbf{P}_{H,m}$ and $\mathbf{P}_{m,H}$ stand

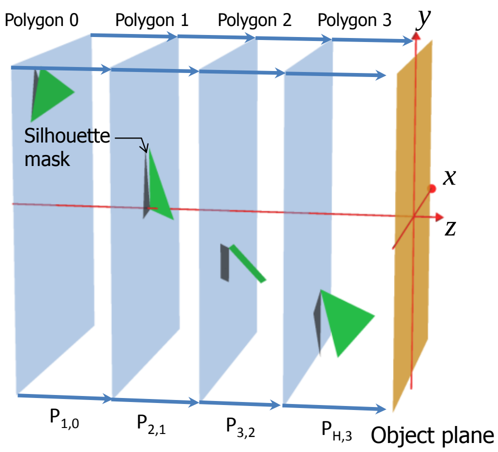

Fig.1 Conventional silhouette light-shielding

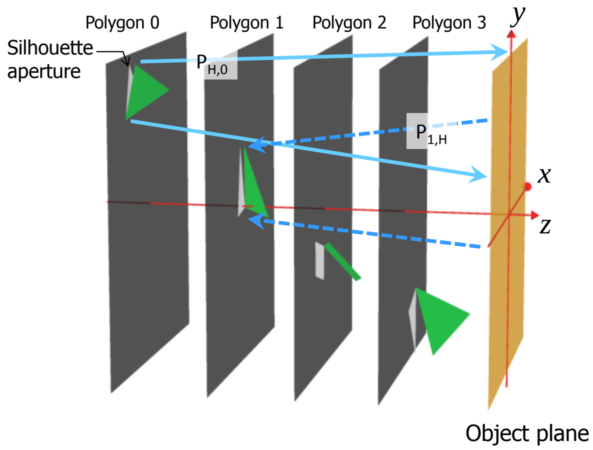

Fig.2 Switch-back technique for accelerating silhouette light-shielding.

for propagation to and from the object plane, respectively, i.e. the Eq.(2) and (3) give forward and backward propagation to the object plane. Let us emphasize that the source or destination filed of the propagation in this case is required only around the polygon unlike Eq.(1) because of masking by the apertures that are inversion of the original silhouette masks. As a result, the computation is definitely speeded up by using Eq.(2) and (3). This is called *switch-back* technique because a couple of forward and backward propagations are repeated the same times as the number of polygons, as shown in Fig.2.

3. More accurate light-shielding

Light-shielding by silhouette-shaped masks is an approximation of actual light-shielding of opaque polygons. Thus, a little light passes through the gap between silhouette-masks. This leakage light causes occlusion errors. To avoid the leakage light, light behind a polygon should be shielded by the polygon-shaped mask in the polygon plane. To do this, the field in the polygon plane must be obtained from $u_m(x,y)$ by using rotational transform [10], and then the masked field is calculated by inverse rotational transform after masking. Therefore, this accurate light-shielding required a double rotational transform for each polygon. This is very time-consuming in the conventional silhouette method because large fields must be rotated. Since the rotated field area is small in the switch-back technique, more accurate polygon masking can be applied to high-definition CGHs [11].

3. Light-shielding in digitized holography

Object-by-object silhouette masking is used in digitized holography [9]. In this case, the mask is obtained from the amplitude image given by numerical reconstruction of the captured object field. However, if the object silhouette changes dependently on the view-point, simple light-shielding using the single silhouette mask causes heavy occlusion errors. To reduce the errors, we propose new technique using multiple-silhouettes taken from different view-points.

4. Conclusion

Recent techniques for hidden-surface removal (light-shielding) are reviewed in high-definition computer holography. The switch-back technique plays an important role for speed-up of the computation. Some CGHs created by using these techniques is demonstrated in the meeting.

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