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Computer-generated holography method based on orthographic projection using depth camera

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Abstract

There are still have many serious problems with the real-existing scenes acquisition and generation of Hologram. In this research, an efficient CGH scheme that using orthographic projection images and depth map for real-existing scenes is proposed. The orthographic projection images and depth map are generated from 3D scanned model which is captured using depth camera. The proposed method generates Multiview images with full scanned real object with not only color information but depth information for hologram generation. The additional depth information can be used in additional artifact. This method reduces the number of angular samplings of the viewpoint images, provides all the human depth cues without producing any visible artifact.

Introduction

Holographic display technique can be realized true three-dimensional (3D) displays where full depth can be observed directly by human eyes. Although, holography has presents so many years, the real-existing scenes acquisition and generation for Hologram still have serious problems. However, with development of the science and technology, the device which extracted 3d information of real-existing scenes is improved such as depth camera, light field camera, etc. However, the extracted 3d information is not enough to describing the realistic scenes for generating synthetic hologram by usual synthetic model.

Hologram generation methods can be classified according to the type of input data: synthetic 3D scenes or multi-view data [1]. Compute a hologram from synthetic 3D scenes is usually sample it set of primitives and calculate the hologram as the Complex light waves scattered by each primitive. In Computer Graphic(CG), 3-D object is made by point based model or polygon based model. For this cause, commonly primitives include point cloud based approach and polygon-based approach.

In the point cloud based approach, the 3D scenes are assumed to be covered by many point light sources, and spherical waves emitted from these point sources are computed and superposed in the hologram plane [2]. This approach is easy to implement and flexible but is very time consuming for full-parallax CGHs because point-based methods need gigantic numbers of point sources to describe photo-realistic effects, and CG shading techniques, such as Phong shading [3] need be computation during in generate CGH. Although there are many techniques proposed for acceleration of this method, but it is hard to create high resolution CGHs of big 3D scenes.

In the Polygon-based approach is used to compute the object field of the occluded 3D scene, the object is considered to be composed of small planar surface light sources that have polygonal shapes, and the wave fields emitted by these polygonal sources are calculated and are superposed in the hologram plane [4]. As for the point cloud based approach, CG shading techniques can be integrated during CGH computation in order to produce photo-realistic effects. However, the propagation computation of complex wave scattered by the polygons is using such as Angular Spectrum diffraction method [5]. Which involves use of the FFT more time-consuming than point cloud approach in computation of the optical field by a single point.

Hologram generation with multi-view data have two kinds approaches: the multi-viewpoint projection based methods and the holographic stereogram approach [1].

Multi-viewpoint projection based methods generate holograms by first acquiring two-dimensional(2D) projections of a 3D scene using a 2D camera array or by shifting a single camera along the vertical and horizontal axis. The number of acquired images should be equal to the number of hologram pixels. Each hologram pixel is then computed by multiplying its corresponding projection image by a given complex point spread function (PSF) and by summation of the resulting inner product [6].

The holographic stereogram approach is another class of CGH computation methods which use multi-view data as input. In this approach, the hologram is spatially partitioned into several holographic elements, called hogels. The hogels angularly multiplex the 2D projections of the scene towards the corresponding viewing directions. This approach is computationally very efficient and does not require as many projection images as for multi-viewpoint projection based methods. Moreover, occlusions and shading of the scene are naturally recorded in the multiplexed 2D views. However, since each hogel only corresponds to a 2D parallax view, the accommodation cue is sacrificed, which strongly limits the naturalism of the perceived 3D effect. Several methods have been proposed to improve the depth illusion provided by the holographic stereogram, including phase-added stereograms [7, 8], diffraction-specific coherent panorama gram [9], and ray sampling plane techniques [10].

Multi-viewpoint projection has mainly three projection type: perspective projection geometry, angular projection geometry, and orthographic projection geometry. Mishina et al. proposed a calculation method for holograms from elemental images captured by integral photography using Fresnel diffraction theory and obtain a complex field of 3D image from the elemental images [11]. However, their method has limited to Fresnel holograms only, which have the perspective projection geometry. Abookasis et al. and Sando et al. proposed hologram calculation methods from angular projections of 3D objects [12, 13]. The angular projection used in their method is an image that we can get after rotating the 3D object about its local coordinate origin and projecting it onto the central transverse plane, i.e. the XY plane [12]. For capture those images with the camera, the camera need to move on a curved surface whose curvature those radius is much larger than the object thickness [13]. N.T. Shaked et al., Abookasis et al., and Sando et al. extended these methods to make angular view point image acquisition easier using a lens array [14], to generate a Fresnel hologram [15, 16], or to generate a full-color Fourier hologram [17].

Jae-Heung park et al. proposed the orthographic projection geometry enable to generate an exact Fourier hologram and Fresnel hologram without any approximations [18,19].

Recently, 3D data acquisition process for real object with depth camera is more and more convenience because of the Software Development Kit(SDK) for depth camera. Thanks to the progress of the depth camera development, with one depth camera we can easily scanned all round real 3D object. Which is work for existing full object depth information and color information with low cost (numbers of camera, calculation time etc.). Although, the occlusion process is included in multi-view images generation.

In this report, we proposed a computer-generated hologram system of a real-existing scene by depth camera which is scanned model of real 3d object. All round real scene captured by depth camera in 3d scan mode, the point cloud model and corresponding color information is processed to generating orthographic projection images and depth map. Hidden point remove was used in point cloud to orthographic projection image (and depth map) conversion. And the hole filling method will be used. Finally, the orthographic projection images and depth map will be used to compute hologram with low angular sampling.

Background

Jae-Heung Park et al. have first reported an initial idea for generating holograms using the orthographic projection images [20]. The use of the orthographic projection geometry can generate an exact Fourier hologram in a straightforward way without any approximations. They also implement this into potable camera pickup system which is using lens array planted camera easily captured integral image generate orthographic projection images to generate hologram [21]. The scheme of the Fourier hologram generation with orthographic view images(OVI) generate from integral image is shown in Figure 1. The CCD camera with micro lens array captured integral image of real. And then multiplication of each OVI by the phase factor of the slanted plane wave. Integrate all the product of the multiplication, the complex field is 3D object at a single in the Fourier plane.

This method can be using the simple manipulation of the projection view images, also made it more convenience to Fresnel and Fourier hologram generation. However, the resolution of orthographic projection image is limited by lens array. The different viewpoints through the objects to each sampling region in the hologram. Each sub-image with random phase are generate the hologram which is equation as below:

$$\mathrm{H}(\mathrm{s},\mathrm{t}) = \iint A_{s,t} \exp[-j2\pi b(ms+nt)]dmdn \qquad (1)$$

In order to break through the weakness of the resolution of OVI, the depth camera is used instead of lens array. Which can be fast and easy scanning full surrounded 3D data of real object. The information can be used for hologram and additional reproduction.

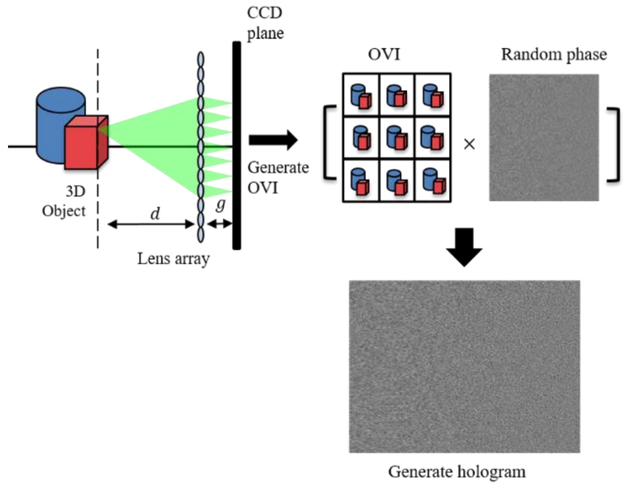

Figure 1. Fourier hologram generation using orthographic view images(OVI) from integral image

Proposed framework

We proposed an efficient scheme that generate orthographic projection image based hologram by point cloud which is scanned by depth camera. Frist, the depth camera acquires all round color and depth information. The second step is the occlusion processing for generate each view point cloud which is low density front surface. In order to increase the resolution of each view images, the hole filling method has been used. And All orthographic projection images was integrated into an arranged align image. Finally, the orthographic projection images and depth map will be used to compute hologram with low angular sampling.

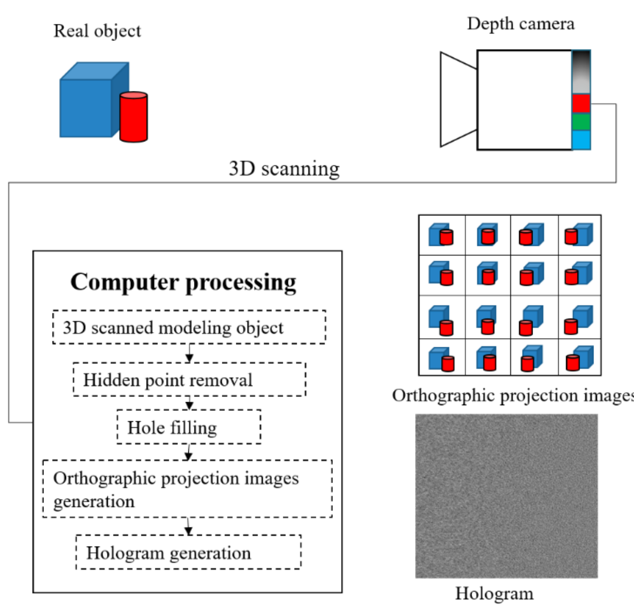

Figure 2. The schematic Diagram of Proposed

3D scene Geometry with 3D scanned information

In proposed scheme, we generated the orthographic projection images from 3D data of scanned which is captured by depth camera.

Figure 3 shows the orthographic projection geometry between 3D object and the view image at the image plane. The angle θ is the angle projection of **r** onto the y-z plane makes with z-axis, and φ is the angle that **r** onto the x-z plane make with z-axis.

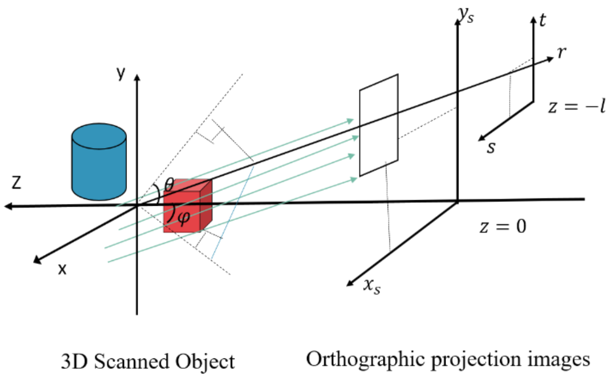

Figure 3. Orthographic projection images extraction from 3D scanned Object

The projection image coordinate (x_s, y_s) in this projection geometry can be written as

$$\begin{cases} x_s = x + ztan\varphi = x + \frac{zs}{l} \\ y_s = y + ztan\theta = y + \frac{zt}{l} \end{cases} \quad (2)$$

Hidden Point Remove

In CGH calculation methods, the hidden surfaces are usually encoded into the hologram, and this case heavy calculation loads and noise. These issues could be potentially being alleviated by removing the hidden surface from the encoding CGH. Also in order to get projective view image, the Hidden Point Remove (HPR) Algorism [22] has been used for 3d scanned data.

The HPR operator can be applied in any dimension. However, it is best understood in 2D. Consider a point $p_i \in P$. Without loss of generality, p_i lies on the X-axis. Using a polar coordinate system (r, θ), we can write $p_i = (r_i, 0)$, where r_i is the distance of pi from C, and the angle with the X-axis is 0. Consider the straight line $\hat{L}$ that passes through $\hat{p}_i$and creates an angle β with the X-axis, as shown in Figure 4.

If the curve $L = (r(\alpha), \alpha)$, which is the source of $\hat{L}$, using the Law of Sines we get:

$$\frac{2R - r_i}{\sin(\pi - \alpha - \beta)} = \frac{2R - r(\alpha)}{sin\beta} \quad (3)$$

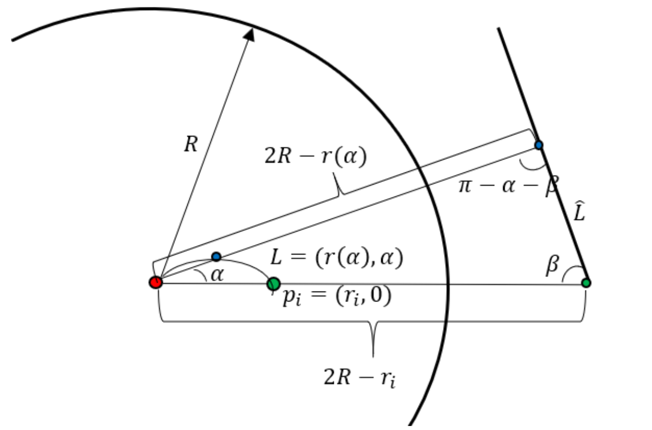

Figure 4.** L **is transformed to** $\hat{L}$ **by spherical flipping.

The remaining point cloud need to increase the density for convert to Multiview images. Figure 5 shows the result of HPR process, (a) is the original point cloud, (b) is the result surface point cloud.

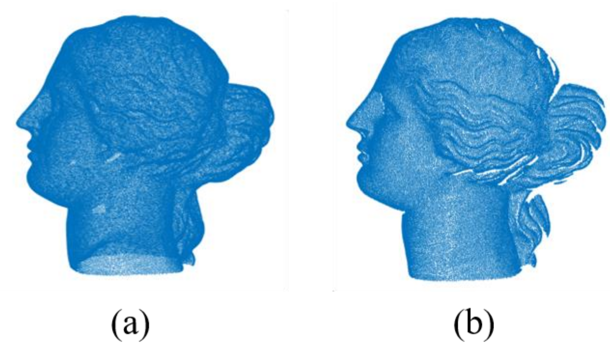

Figure 5. The Result of HPR.

Depth map filling

In order to get higher resolution of each view images we need to convert the surface point cloud to 2D image (depth map). In the proposed method, we choose Morphological reconstruction method which is useful for constructing an image from small components or for removing features from an image, without altering the shape of the objects in the image.

Morphological reconstruction has been used in detect and fill object holes. Morphological reconstruction has a broad spectrum of practical applications, each characterized by the selection of the marker and mask images. For example, let I denote a binary image and suppose that we choose the marker image, F, to be 0 everywhere except on the image border, where it is set to 1 - I:

$$F(x, y) = \begin{cases} 1 - I(x, y) & if\ (x, y)\ is\ on\ the\ border\ of\ I \\ 0 & otherwise \end{cases} \quad (4)$$

Then,

$$H = [R_{ic}(F)]^C \quad (5)$$

Figure 6 shows the hole filling result with Morphological reconstruction algorism. Fig. 6 (a) is the remained surface point cloud, (b) is converted depth map from (a) using Morphological reconstruction algorism.

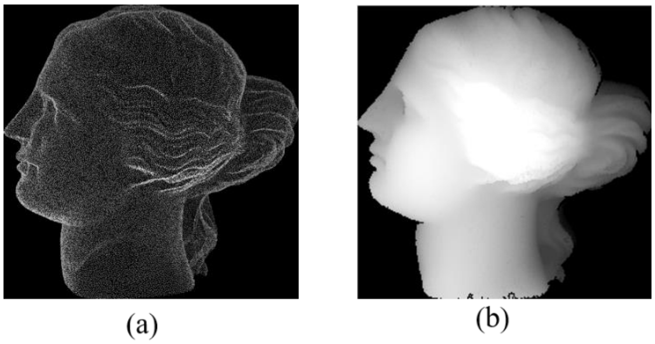

Figure 6. Depth map filling with Morphological reconstruction.

Experimental results

In experiment, we used the Intel RealSense F200 depth camera (Figure 7) for 3D scanning the real object which has 80,589 points for 'Venus', 86,121 points for 'girl'. A normal specification PC with Intel(R) Core(TM) i7 CPU, a main memory of 8.00GB, and an operating system of Microsoft Windows 10 64bits as well as NVIDIA GeForce GTX 560 Ti.

Table 1 is the specification of the Intel RealSense F200, and Fig. 7 shows the structure of F200. The final generated Orthographic Projection images of 'Venus' are shown in Figure 8., and Fig. 9 (a) is the generated hologram of Fig. 8, and Fig. 9(b) is the optical reconstruction of Fig 9 (a).

Table 1. Specification of Intel RealSense F200

Specification	F200 Camera
Depth Technology	Coded Light
Depth/IR	VGA at 300fps
Depth Field of View	H:73, V:59, D:90

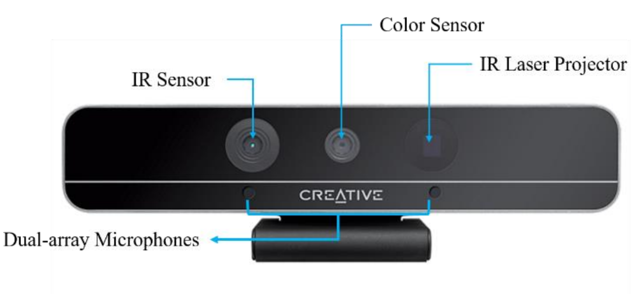

Figure 7. Intel RealSense R200 depth camera

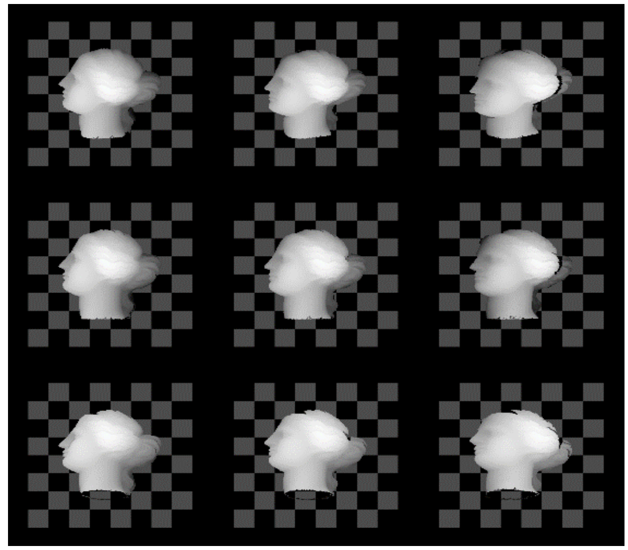

Figure 8. Orthographic projection images generated from 3D scanned of 'Venus'

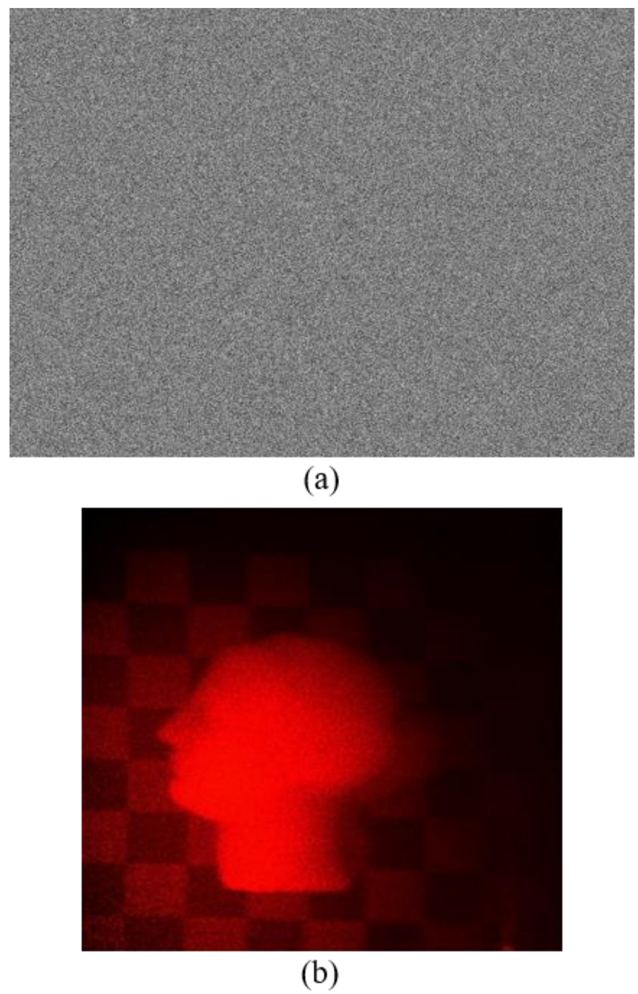

Figure 9. (a) Orthographic projection images based method generated hologram. (b) optical reconstruction of 'Venus'

Conclusion

We proposed an efficient scheme that generate orthographic projection image by low density point cloud which is scanned by depth camera. The 3d scanned point cloud has low density to describing the realistic scenes for generating CGH. For overcome the limitations, the proposed used orthographic projection images with depth map. The proposed method provides all the human depth cues and accurate shading of the scene without producing any visible artifact and reduces the number of angular samplings of the viewpoint images.

The experiment result shows that scheme have limitation caused by depth field of depth camera. The compactness and precise of 3D scanned model will have more good result of surface point cloud to depth map conversion. Figure 10 is the 3D scanned model 'girl' with low quality conversion.

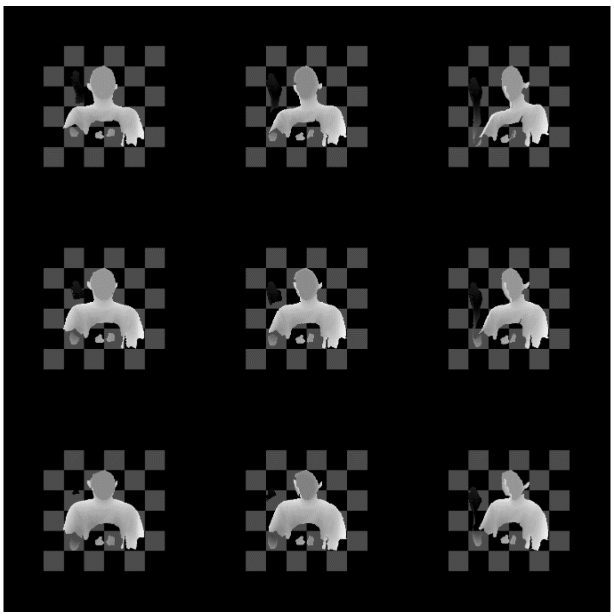

Figure 10. Orthographic projection images generated from 3D scanned of 'girl'

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