Controllable Color Particles in a 3D Crystal Projecting Multiple Dynamic Full-Color Images

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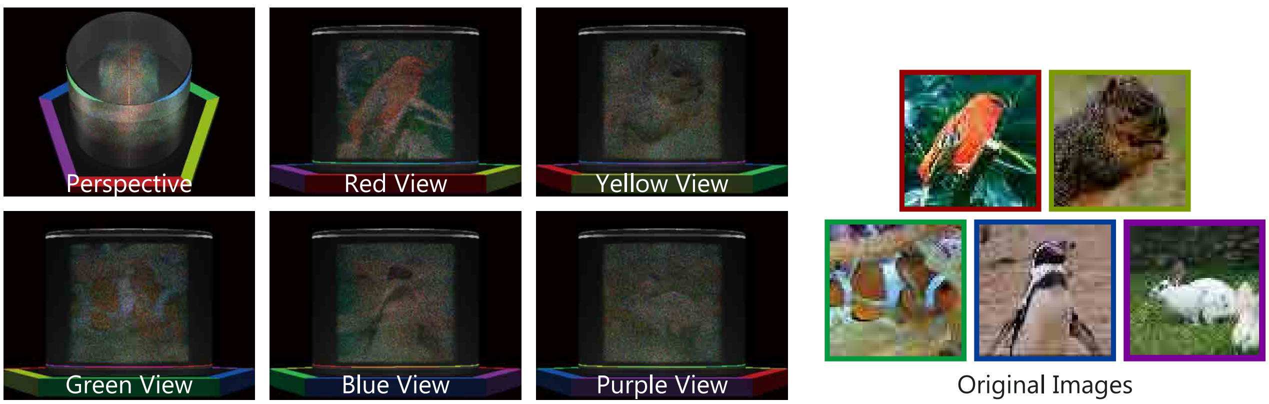

Figure 1: Controllable color particles in a 3D crystal projecting five dynamic full-color images (see the supplementary video). All the footages used as the original images can be found at Videvo.net (https://www.videvo.net/).

ABSTRACT

In this study, we present a 3D structure projecting multiple dynamic full-color images in different directions. The 3D structure is represented as a crowd of controllable color particles rendered in a cylindrical 3D crystal with a CG software. We confirmed that five images could be successfully observed from different viewpoints. Such 3D structures can be applied to information service systems including digital signage and security system.

CCS CONCEPTS

•Computing methodologies →Volumetric models; •Applied computing →Media arts; •Information systems →*Multimedia information systems;*

KEYWORDS

Media Art, Steganography, 3D Crystal, Volumetric Display

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1 INTRODUCTION

A 3D structure depicted on the book "Gödel, Escher, Bach [Hofstadter 1979]" projects different three binary images, which are formed of the title's initials "G", "E", and "B", in orthogonal directions. Such a unique 3D structure is known as a 3D ambigram or shadow art [Mitra and Pauly 2009], and has been familiar as an artistic medium. In previous studies, we proposed an algorithm, based on a concept similar to a 3D ambigram, to design a 3D structure projecting multiple gray-scale images in different directions [Hirayama et al. 2016a; Nakayama et al. 2013]. The proposed algorithm offers greater flexibility to the number and projection directions of the images than the conventional 3D ambigram. We demonstrated the algorithm by rendering the designed 3D structures on clear glass solids with laser-induced tiny cracks (3D crystals). Each of the images can be obtained only from a prescribed viewpoint. This steganographic feature provides the fun of finding hidden information and attracts observers to it as media art. In addition, we believe our method has the potential to be applied to information service systems such as digital signage by implementing the algorithm on controllable color particles instead of the laser-induced cracks. A practical way to realize such particles in the real world is to use volumetric 3D displays [Geng 2013]. In this study, we demonstrate a 3D crystal including the particles rendered with CG, projects five dynamic full-color images as shown in Figure 1.

2 OUR APPROACH

With Figure 2, we describe the algorithm to design a 3D structure projecting five full-color images in different directions. The 3D structure is composed of 64 × 64 × 64 volume elements (voxels). In each voxel, there are red, green, and blue particles, the numbers of which are represented by $V_R(x, y, z)$, $V_G(x, y, z)$, and $V_B(x, y, z)$, respectively. These voxel values are determined by the original images virtually set up on each projection direction.

Let us consider the case where a voxel value at (x, y, z) is determined. The voxel is projected at (u_i, v_i) on the original images along w_i, where i is an image number and takes 1, ..., 5. The u_i-, v_i- and w_i-axes represent the horizontal component, vertical component, and the projection axis of the projected images, respectively. Note that w_i is bent by the refraction at a curved surface [Hirayama et al. 2016c]. To increase the image quality of the projected images, we used the iteration calculation proposed in the previous work [Hirayama et al. 2016a]. Since we treat the full-color images, the following calculation is applied to the three color components.

First, the voxel value in the k-th loop $V(x, y, z)^{(k)}$ is determined as the geometric mean of the pixel values of the recorded images $R_i(u_i, v_i)^{(k)}$ as follows:

$$V(x, y, z)^{(k)} = \prod_{i=1}^{N} \sqrt[N]{R_i(u_i, v_i)^{(k)}}. \quad (1)$$

In this case, $N = 5$. As the initial recorded images $R_i(u_i, v_i)^{(0)}$, the ideal original images $I_i(u_i, v_i)$, which are required to be projected, are used. Next, the projected images $P_i(u_i, v_i)^{(k)}$ from the 3D structure are expressed as a summation of the voxel values along w_i as follows:

$$P_i(u_i, v_i)^{(k)} = \sum_{w_i} V(x, y, z)^{(k)}. \quad (2)$$

After being normalized, $P_i(u_i, v_i)^{(k)}$ ideally should have the same values as $I_i(u_i, v_i)$. In the next step, the recorded images used in the next (k-th) loop are updated as follows:

$$R_i(u_i, v_i)^{(k+1)} = R_i(u_i, v_i)^{(k)} \frac{I_i(u_i, v_i) + C_1}{P_i(u_i, v_i)^{(k)} + C_2}. \quad (3)$$

Here, C_1 and C_2 are constants. The projected images would be improved with respect to the iteration number.

In this study, 6-second 10-fps dynamic full-color images (64 × 64 pixels) were used as the original dynamic images. Voxel values were calculated for every frame (60 frames in total) and were normalized such that the maximum value is 10. Under the assumption that the particles exist randomly in the voxels, coordinate data of particles were created from the voxel data. With the CG software MAYA, 60 frames of the particles were placed into a glass cylinder and

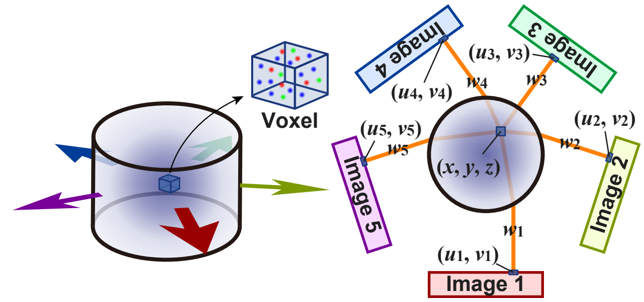

Figure 2: Overview of the designed 3D structure (left), and description of how to determine a voxel value (right).

rendered consecutively. Figure 1 shows the rendered images from different view points. The five different full-color images can be successfully observed. We also confirmed that dynamic images can be observed as shown in the supplementary video.

3 CONCLUSION AND FUTURE WORK

In summary, we demonstrated that the 3D structure projected the five dynamic full-color images in the different directions. The 3D structure was represented as the crowd of controllable color particles rendered in the cylindrical 3D crystal with the CG software.

For practical use of our method, a high-resolution volumetric 3D display is required. For example, laser-irradiation-based volumetric displays (e.g., volumetric bubble display [Kumagai et al. 2017]) seem to be a possible solution. In addition, we are also developing a new approach of volumetric display [Hirayama et al. 2016b]. Although the 3D structure was rendered with CG in this study, rendering the designed 3D structure using such volumetric display in the real world is an interesting future research topic.

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