3-D crystal with curved surface projecting multiple 2-D images

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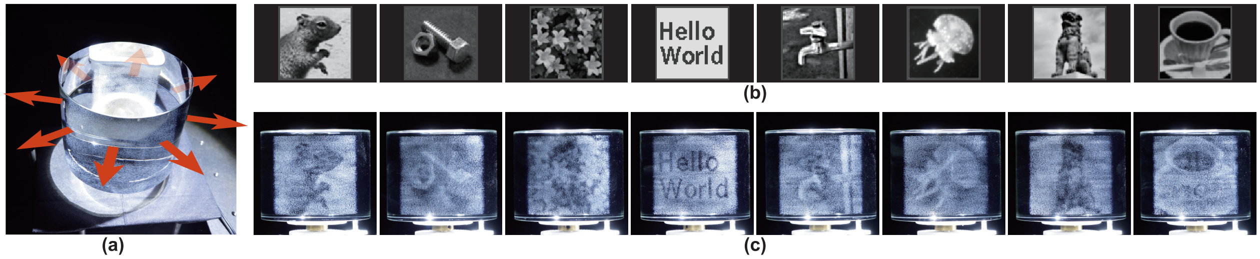

Figure 1: *Cylindrical 3-D crystal projecting eight images. (a) Perspective view. (b) Original images (64 × 64 pixels) recorded on the glass. (c) Pictures taken from different viewpoints.*

1 Introduction

In the previous work, we developed an algorithm to design an unique 3-D structure [Nakayama et al. 2013]. A cubic 3-D crystal, on which the 3-D structure designed by the algorithm was rendered, can project three 2-D images to different directions. Moreover, we demonstrated a spherical 3-D crystal projecting four images to show an extension to the algorithm [Hirayama et al. 2016]. These structures can provide multiple 2-D images independently; thus, they could be applied to information service systems.

However, the images projected from the 3-D crystal with curved surface (e.g. sphere and cylinder) are distorted because of the refraction. Therefore, we propose a refraction-compensating algorithm based on the original algorithm to demonstrate a 3-D crystal that has curved surface and projects multiple images for different view directions as shown in Figure 1. By using 3-D crystals with curved surface, the view directions of images can be set arbitrary. In addition, we can remove the limitation of the original algorithm. That is, the projection directions from the 3D crystal with curved surface can be set at 180° opposite each other.

2 Our Approach

First, we simulated spherical 3-D crystals which project four images to different directions (Figure 2a) with computer graphics. We determined the four projection directions of the images to be at 45° apart from each other. The 3-D structures rendered on 3-D crystal are made up of a cloud of small points. The numbers of the points per unit volume are refered as the voxel value and are determined by multiplying the pixel values of the original images. Here, the pixel values corresponding to the locations on where the voxel is projected to each view direction are used for the calculation.

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In the original algorithm, bending of the projection directions due to the light refraction at the curved surface is not concerned. Therefore, the projected images from the spherical 3-D crystal are stretched and distorted (Figure 2b). By contrast, the projected images in Figure 2c show that the refraction effect is compensated because the appropriate pixel values corresponding to the bended projection directions are used in the proposed algorithm.

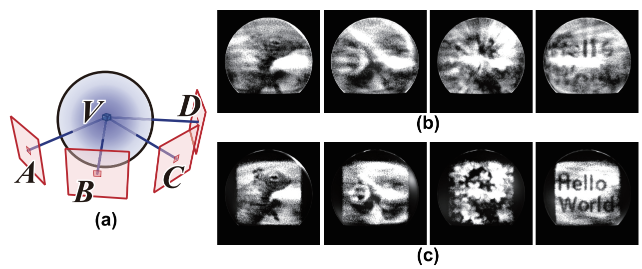

Figure 2: *Simulation results. (a) Scheme of the setup. Projected images of (b) the original algorithm and (c) the proposed algorithm.*

In the original algorithm based on the premise that the projection directions are perpendicular to flat faces, they cannot be set at 180° opposite each other because the miror-reversed image is projected to opposite direction. Meanwhile, in the proposed algorithm, the limitation can be removed owing to the refraction. Figure 1a shows the prototype of the 3-D crystal projecting eight images (Figure 1b) to different eight directions at 45° apart from each other. We can observe the eight images from different view points (Figure 1c).

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References

HIRAYAMA, R., NAKAYAMA, H., SHIRAKI, A., KAKUE, T., SHIMOBABA, T., AND ITO, T. 2016. Image quality improvement for a 3d structure exhibiting multiple 2d patterns and its implementation. *Optics Express 24*, 7, 7319–7327.

NAKAYAMA, H., SHIRAKI, A., HIRAYAMA, R., MASUDA, N., SHIMOBABA, T., AND ITO, T. 2013. Three-dimensional volume containing multiple two-dimensional information patterns. *Scientific Reports 3*, 1931.