Printing 3D Light Field with 1D Halftone Screening

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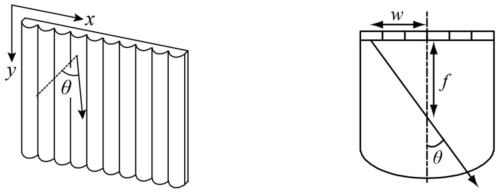
1. Introduction

Lenticular printing is an old technique, which enables stereoscopic 3D by recording pictures taken by two or more cameras onto one medium. It is often awkward in its transition between insufficient images due to sparse sampling from the light space. In this paper, we propose a method for making 3D print which reproduces light space represented as a light field[1] by introducing an ideal halftone screening.

2. 1D screening for printing light field

We print three-dimensional (3D) light field by lenticular printing. Each 2D slice $S_\theta(x, y)$ in the 3D light field represents an image viewed from the azimuth of θ. The rays are collected from all slices and printed together behind the lenticular lens pixel by pixel as illustrated in Fig.1. Required azimuth θ for each sub-pixel located at distance w from the optical axis is given as $\arctan(w / f)$, where f denotes the focal length of the lenticular lens.



(a) (b)

Fig. 1. Lenticular printing

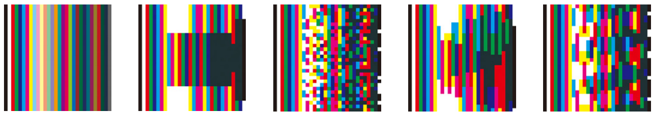
Numbers of images captured from horizontally different positions are required to create 3D light field[2]. We take pictures with a camera moving on the straight rail. As images are in perspective, we collect rays passing through the focal plane in the specific direction to make a slice of the light field. Fig.2 shows an example of captured images and representative slices created from them. Note that objects are projected in parallel horizontally, while remaining perspective vertically.

(a) captured image (b) $\theta = 0°$ (c) $\theta = 11°$

Fig. 2. Creating 3D light field

We need to employ halftone screening for printing light field in full color. One-dimensional (1D) AM screening[3] is proposed for lenticular printing which controls tone by series of small binary dots vertically connected instead of 2D dots used in general printing as shown in Fig.3(b). Alternatively, 1D-FM screening represents tone by density of isolated dots as shown in Fig.3(c). They make possible to include maximum number of slices in a pitch of lenticular lens, and make the smoothest transition in parallax with specific resolution in plate making.

1D-AM screening, however, locates halftone dots densely around particular lines that are undesirably noticeable on 3D print. On the other hand, 1D-FM screening disperses halftone dots over the region, while solitary dots make image impression noisy.



(a) (b) (c) (d) (e)

Fig. 3. 1D screening : (a) an array of colors to be printed, (b) 1D-AM, (c) 1D-FM, (d) displaced 1D-AM, (e) our 1D-AM screening.

To solve the problem on 1D-AM screening, we displace each series of dots by which dots are located around lines inclined independently each of the four primary colors as shown in Fig.3(d).

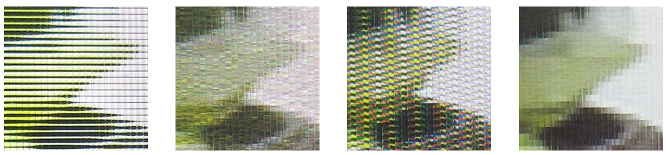
Although this arrangement reduces partiality of dots, a new problem known as moiré is expected due to regular arrangement as often seen in usual color printing. The second strategy on improving screening is to diffuse regularity by dividing each series of dots into a few fragments with maintaining probability of dots and spaces as shown in Fig.3(e). Furthermore, dividing into independent number of fragments to each of the four primary colors will gain dispersion.

3. Result

Fig. 4. Printed 3D light field

Fig.4 shows three different views of a trial product. We inserted 48 parallax images into a lenticular cell (50lpi) with 0.6 degrees of interval in azimuth using a 2400dpi resolution plate making system, so a quite smooth motion parallax was reproduced.

Fig.5 shows magnified images of a 3D print with each of proposed 1D screenings. While horizontal lines appear conspicuously with 1D-AM, the image becomes gritty-textured with 1D-FM. Displacement on 1D-AM then makes noticeable moiré. Finally, all artifacts are disappeared with our 1D-AM and the image is reproduced smoothly.



(a) (b) (c) (d)

Fig. 5. Comparison of 1D Screening (magnified) : (a) 1D-AM, (b) 1D-FM, (c) displaced 1D-AM, (d) our 1D-AM screening.

References

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