A SIMULTANEOUS VIEW INTERPOLATION AND MULTIPLEXING METHOD USING STEREO IMAGE PAIRS FOR LENTICULAR DISPLAY

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ABSTRACT

Nowadays, the slanted lenticular display becomes a representative one among the commercially introduced autostereoscopic displays.

The paper presents a simple method to correct the lenticular alignment error by compensating the correction coefficients to the view number determination formula. Then, based on the corrected view numbers, the proposed algorithm simultaneously performs floating-point viewpoint generation and multiplexing on the scanline using the stereo image pairs and its depth information.

Experimental results show that lenticular images, in which distortion and artifact due to lenticular alignment error are considerably reduced, are generated rapidly by using the proposed algorithm.

***Index Terms*—**Three-dimensional displays, Stereo vision.

1. INTRODUCTION

In the autostereoscopic displays, a viewer can see 3D images without any auxiliary devices, and recently there are many researches and studies for autostereoscopic display method for augmenting the reality and 3D effect. Among the autostereoscopic displays, lenticular display is the most commercially progressed autostereoscopic display, and the slanted lenticular display is generally used for the reduction of the Moiré patterns and balance of the resolution in vertical and horizontal directions [1].

Similar to other flat panel based autostereoscopic display methods, for lenticular display, several images which have different viewpoints are multiplexed to a lenticular display. Fig. 1 shows an example of the multiplexing process of the 9-view lenticular display. Each RGB position of a pixel in the image has its own view number for lenticular display. For example, if the view number of red component on a pixel in the multiplexed image is three, then only the red color of the pixel at the same coordinates in the third-view image can be assigned. If the view determination formula provides wrong view number for each pixel, then the color values in the pixels which have the misassigned view numbers can be a main reason of the image distortions such as boundary dislocation [2].

A goal of this paper is to propose a simultaneous multiplexing and view interpolation method by using a stereo image pair and its depth image for fast multi-view lenticular display. Before the introduction of the proposed method, the paper presents a simple lenticular misalignment correction method just by compensating some correction coefficients to the view number determination formula. The simultaneous multiplexing and view interpolation method can support the floating-point view number that is obtained from the corrected view number determination formula.

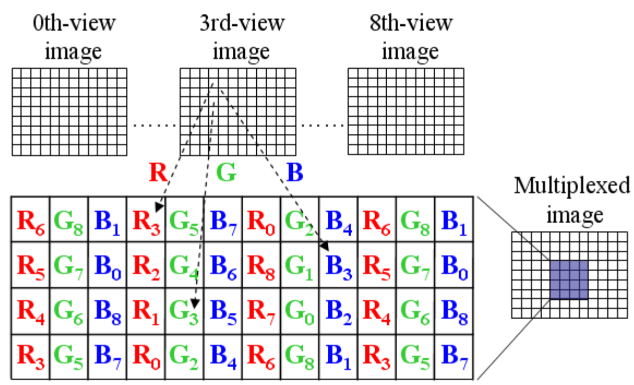


Fig.1. Multiplexing process of the conventional 9-view lenticular display.

2. A MISALIGNMENT CORRECTION METHOD BY USING THE CORRECTION COEFFICIENTS

The view number determination formula for each sub-pixel (*x, y*) in the multiplexed image is described as follows,

$$n(x,y) = (ax - by + c) \bmod N_{tot} \tag{1}$$

where $n(x,y)$ is the view number of (*x, y*), N_{tot} is the total number of views, and *a*, *b*, and *c* are constants defined by lenticular alignment. In general 9-view lenticular displays, *a*=2 and *b*=1. However, if the lenticulae are misaligned in translation and rotation, the original view number determination formula cannot assign correct view number to the sub-pixels.

These lenticular misalignment errors can be reduced by adding correction terms to eq. (1). Then eq. (1) becomes

$$n(x,y) = \{(a+a_{cor})x-(b+b_{cor})y+c+c_{cor}\} - \left\lfloor \frac{(a+a_{cor})x-(b+b_{cor})y+c+c_{cor}}{N_{tot}} \right\rfloor \times N_{tot} \quad (2)$$

where a_{cor}, b_{cor} and c_{cor} are the compensation coefficients for correction of the lenticular alignment error.

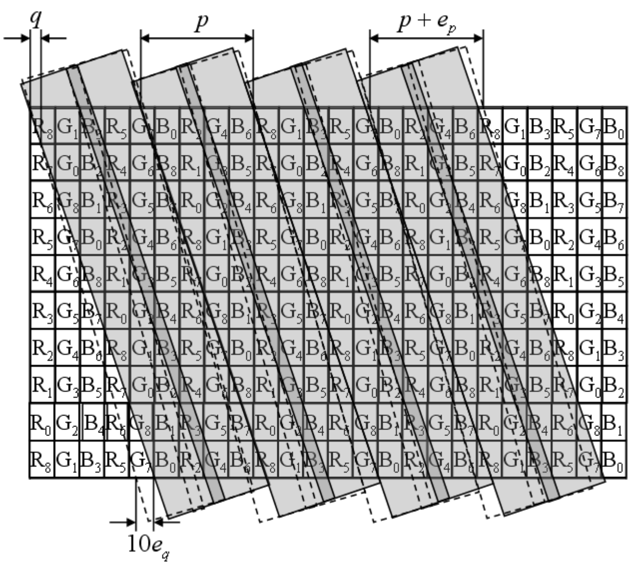


Fig. 2. Alignment of lenticulae in ideal case (solid line) and with rotational alignment error (dotted line) [2].

Let p and q be the lenticular pitch and horizontal shift of a lenticular between successive rows, respectively, and e_p and e_q be the error of p and q, respectively, as shown in Fig. 2. In general 9-view lenticular displays, p=4.5 and q=0.5. And $|e_p|$ and $|e_q|$ can be calculated as follows [2],

$$|e_p| \approx \frac{p^2 N_{cch}}{3N_{tot}N_w} \qquad |e_q| \approx \frac{pN_{ccv}}{N_{tot}N_H} \quad (3)$$

where N_{ccv} and N_{cch} are the number of color changes along the horizontal and vertical directions, respectively, and N_H and N_w are vertical and horizontal resolution of the LCD panel, respectively. Then the corrected coefficients $a' = a + a_{cor}$ and $b' = b + b_{cor}$ can be acquired by simple calculation described as follows,

$$a' = a + a_{cor} = \frac{N_{tot}}{p+e_p} \quad (4)$$

$$b' = b + b_{cor} = \frac{q+e_q}{q} \quad (5)$$

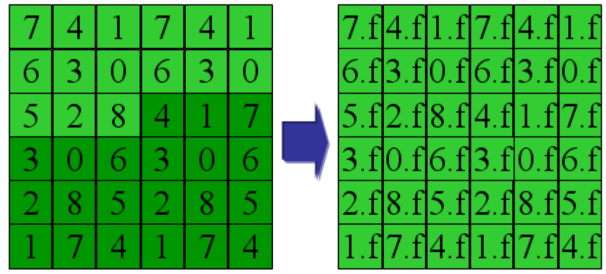


Fig. 3. Conversion from integer value view numbers to corrected floating-point view numbers.

3. A PROPOSED SIMULTANEOUS VIEW INTERPOLATION AND MULTIPLEXING METHOD

In the paper, we assume $N_{tot} = 9$. The proposed algorithm uses the left-most and right-most view images and its depth value that are generated from computer graphics, or stereo images of which depth information is computed by computer vision techniques or acquired from particular devices. The correspondences of the stereo image pairs are assumed to be on the scanline. The size of each view image is one third for the vertical line and one third for the horizontal line of the multiplexed image, where the multiplexed image has the same resolution as the LCD. And we only deal with one sub-pixel component among the R, G, B components, since the other two components can be processed in the same way.

Mapping relation between pixels of the multi-view images and the multiplexed image is calculated by using the depth information and the corrected view number determination formula. Color values of the corresponding left and right pixels are sequentially interpolated and mapped to the locations of the multiplexed image. A method to remove the holes is also processed on the scanline.

3.1. Simultaneous View Interpolation and Multiplexing

Let $d(x,y)$ be a disparity value of (x, y) in the left-most view image, and i be an integer value view number. If there are no holes or overlaps, then (x, y) in the left-most view image, $(x-(i+0.5)d(x,y)/9,\ y)$ in the (i+0.5)th view image, and $(x-d(x,y),\ y)$ in the right-most view become a corresponding point.

Let (x_c, y) be a current pixel in the left-most view image and (u,v) denote the position that satisfies $|i+0.5-n_f(u,v)| \le 0.5$ in a 3×3 region centered at $(3(x_c - \lfloor (i+0.5)d(x_c,y)/9+0.5 \rfloor), 3y)$ in the multiplexed image, where n_f is the floating-point view number of the sub-pixel (u,v). Then the color value $I_n(u,v)$ is estimated, which corresponds to the color value at (u/3, v/3) in the n_f th view image.

Let (x_n, y) be the corresponding point in the left-most view image to the pixel (u,v) in the multiplexed image, whose view number is n_f. If we assume $d(x_c, y) = d(x_n, y)$, then the position of (x_n, y) can be calculated as follows,

$$x_n = \frac{u}{3} + \frac{n_f}{9} d(x_c, y) \tag{6}$$

However, actual $d(x_n, y)$ may not be equal to $d(x_c, y)$. If $|d(x_c, y) - d(x_n, y)| \le 1$, then the corresponding point of (u,v) should be adjusted with assumption of linear interpolation of the disparity between $d(x_c, y)$ and $d(x_n, y)$ to be $\tilde{x}_n$, which satisfies the following two equations.

$$d(\tilde{x}_n, y) = \frac{(\tilde{x}_n - x_c) d(x_n, y) + (x_n - \tilde{x}_n) d(x_c, y)}{x_n - x} \tag{7}$$

$$\tilde{x}_n - \frac{n_f(u,v)}{9} d(\tilde{x}_n, y) = \frac{u}{3} \tag{8}$$

From the upper relationship, $\tilde{x}_n$ is estimated as follows,

$$\tilde{x}_n = x_c + \frac{\frac{u}{3} - x_c + \frac{n_f(u,v)}{9} d(x_c, y)}{\left\{1 - \frac{n_f(u,v)}{9(x_n - x_c)} \left(d(x_n, y) - d(x_c, y) \right) \right\}} \tag{9}$$

Finally $I_n(u,v)$ is determined as follows.

$$I_n(u,v) = \begin{cases} \frac{9 - n_f(u,v)}{9} I_l(\tilde{x}_n, y) + \frac{n_f(u,v)}{9} I_r(\tilde{x}_n - d(\tilde{x}_n, y), y) \\ \qquad \text{if } |I_l(\tilde{x}_n, y) - I_r(\tilde{x}_n - d(\tilde{x}_n, y), y)| \le thresh \\ I_l(\tilde{x}_n, y) \quad \text{otherwise} \end{cases} \tag{10}$$

where $I_l(x, y)$ and $I_r(x, y)$ are color values of (x, y) in the left-most and right-most view images, respectively.

Else if $|d(x_c, y) - d(x_n, y)| > 1$, then we can predict there occur holes or overlaps between (x_c, y) and (x_n, y). In this case, we estimate $\tilde{x}_n$ and $I_n(u,v)$ by assuming $d(x_n, y) = d(\tilde{x}_n, y)$.

The estimation of $\tilde{x}_n$ and assignment of $I_n(u,v)$ are repeated from *i*=0 to *i*=8 for a current pixel (x_c, y). And the procedure is continued pixelwise on the scanline.

3.2. Hole Filling

To find occurrence of the holes, define the difference between the distances from the left-most view image to the *i*th-view image of the previous $(x_c - 1, y)$ and current (x_c, y) pixels as follows,

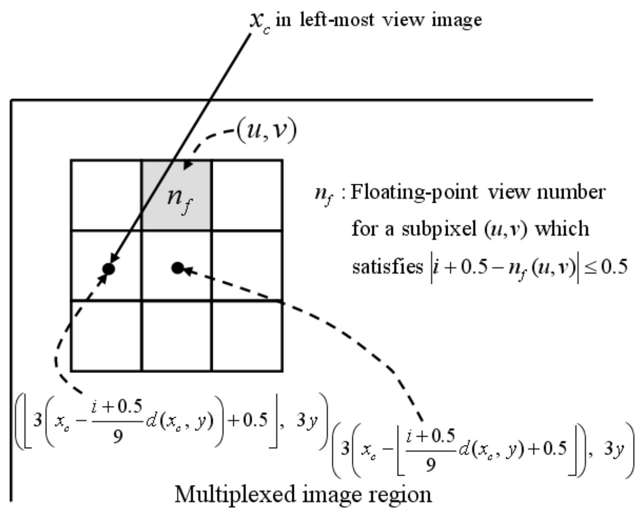


Fig.4. Selection of a pixel in a 3×3 region in the multiplexed image.

$$D_H(i) = \frac{i+0.5}{9} d(x_c - 1, y) - \frac{i+0.5}{9} d(x_c, y) \tag{11}$$

If $D_H(i)$ is negative, the disparity value of the previous pixel is shorter than that of the current pixel, thereby overlapping the pixels. Then, the position mapped from the previous pixel is replaced by the current pixel. Else if $D_H(i)$ is positive, we can predict that holes can occur at pixels from $(x_c - \lfloor (i+0.5) d(x_c - 1, y)/9 + 0.5 \rfloor, y)$ to $(x_c - \lfloor (i+0.5) d(x_c, y)/9 + 0.5 \rfloor, y)$ in (*i*+0.5)th-view image. The length of the hole in the (*i*+0.5)th-view image becomes $D_H(i)$. To remove the holes, we assume that the pixels from $(x_c - D_H(i), y)$ to $(x_c - 1, y)$ in the left-most view image have the same disparity value of $d(x_c, y)$. And re-perform the simultaneous view interpolation and multiplexing method to the pixels from $(x_c - D_H(i), y)$ to $(x_c - 1, y)$ in the left-most view image for filling of the holes. In this case, the holes are filled by the corresponding color values in the right-most view image.

4. EXPERIMENTAL RESULTS

The proposed method was applied to stereo video sequences with depth information generated by computer graphics based on OpenGL. The display device was the 9-view lenticular display system manufactured by Samsung SDI. The implemented program determined the view number of a pixel based on eq. (1) for the original case and eq. (2) for the corrected case, and lenticular parameters are calculated using eq. (4) and (5). The results were $a' = 1.999$ and $b' = 1.02$. And we set $c = 11520$ and *thresh*=15. The resolution of the multiplexed image was 1280×1024, which correspond to the resolution of the display system.

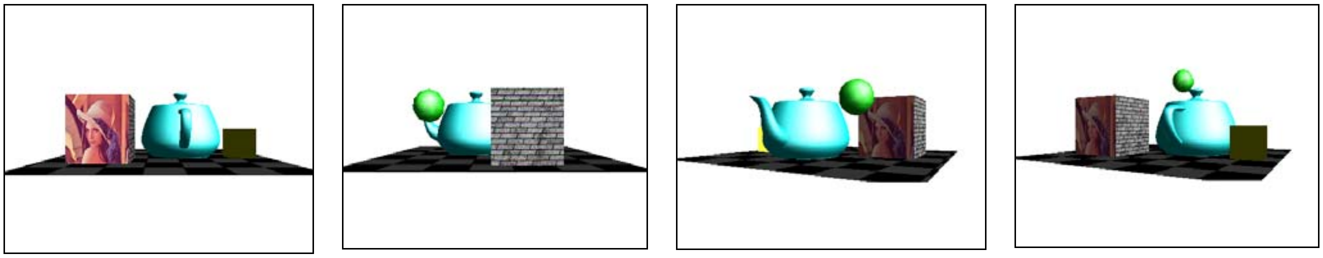
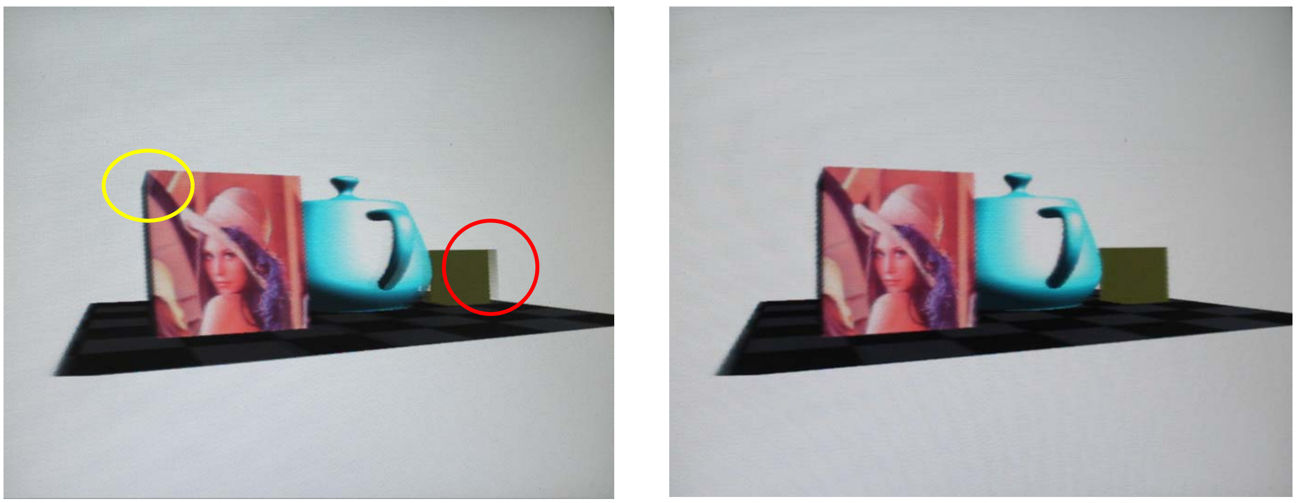


Fig. 5. Selected images of the test sequence from OpenGL API.



(a) (b)

Fig. 6. . Lenticular display results for each case, (a) Original view number determination formula + 9-view mapping, (b) Corrected view number determination formula + floating-point view mapping.

Figure 6 (a) is a picture of the test lenticular image generated from the original view number determination formula and integer value views mapping. But, as shown in the circled regions, the boundaries are dislocated due to incorrect assignment of view numbers for each sub-pixel by using the original determination formula, in which lenticular misalignment errors are not considered. In Fig. 6 (b), the image was generated from the corrected view number determination formula and floating-point views. In the image, we can recognize that the dislocations were considerably reduced.

And we verified the simplified version of the proposed algorithm is suitable for implementation in the 3D graphics processor for fast lenticular display [3].

5. CONCLUSION

In this paper, we proposed a simultaneous floating-point view generation and multiplexing method for fast lenticular display and correction of image distortions caused by the integer value view determination. Because the proposed algorithm is simple and uses small memory space, the algorithm could be implemented in the 3D graphics processor for real-time generation of lenticular images.

ACKNOWLEDGEMENT

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