Measurement of Moiré Patterns in 3D Display

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ABSTRACT

The moiré pattern can be produced when developing 3D displays which can lead to a 3D quality degradation. A measurement algorithm is required to estimate how much moiré pattern has occurred. In this paper, we propose a measurement algorithm that can calculate the moiré artifact generated in displays.

1 INTRODUCTION

The moiré pattern appears when two or more layers of transparent regular grids are overlapped. The LCD (OLED) pixel grid and the lenticular lens are periodic in auto-stereoscopic 3D multi-view display. The moiré effect is observed when the periodic layers of (LCD, OLED) pixel grid and the 3D optics (such as lenticular lens, parallax barriers, or slit barrier) in auto-stereoscopic 3D displays produce interference patterns. The 3D moiré also appears to have periodic pattern. This property is analyzed to determine whether 3D moiré is observed on the virtual image of 3D displays.

The visible additional frequencies in 3D design can cause 3D quality degradation. To avoid the moiré artifacts induced by the panel and 3D optics, several designs have been studied. [1-3] We propose a measurement algorithm based on Fourier transform which can calculate the generated moiré artifact in displays.

2 METHOD

Moiré artifacts are modeled by a spectral model based on Fourier analysis [4,5]. The spectral model of 3D displays can be a function is composed by spectral frequency of pixel structures

$$M_p = \frac{\tau_H}{T_H}\, sinc(\tau_H\, u) * \frac{\tau_V}{T_V}\, sinc(\tau_V\, v)$$

where T_H , T_V , τ_H , and τ_V are horizontal pixel pitch, vertical pixel pitch, horizontal pixel pitch without black matrix and vertical pixel pitch without black matrix, respectively.

The spectral frequency of 3D optics can be simplified by sinusoid function such as

$$M_o = \tau_L\, f_L sinc\big(\tau_L(u\cos\theta + v\sin\theta)\big).$$

where θ is slanted angle and L is lens pitch. To measure a moiré, white test image is used and the acquisition of camera shall have greater resolution than the real 2D display resolution.

The following measuring procedure is followed. For some pixels indicated by the horizontal line in the captured 3D moiré image, the intensity variation in the spatial domain is firstly analyzed. The smoothing filter (for example, 8 x 8 window) is applied to the captured image in order to remove the effect of black matrix in the 2D panel and the effect of lens barrier in the lenticular lens sheet that is attached on the front side of the 2D panel. The intensity variation in the spatial domain for the processed image by the smoothing filter is secondly analyzed. The frequency information for the above selected line is analyzed by the Discrete Fourier Transformation. Finally, it is checked whether the main frequency showing the maximum amplitude is found and that frequency is reported. On the contrary, the main frequency is not detected for the captured white image on a 3D display from which 3D moiré is not observed.

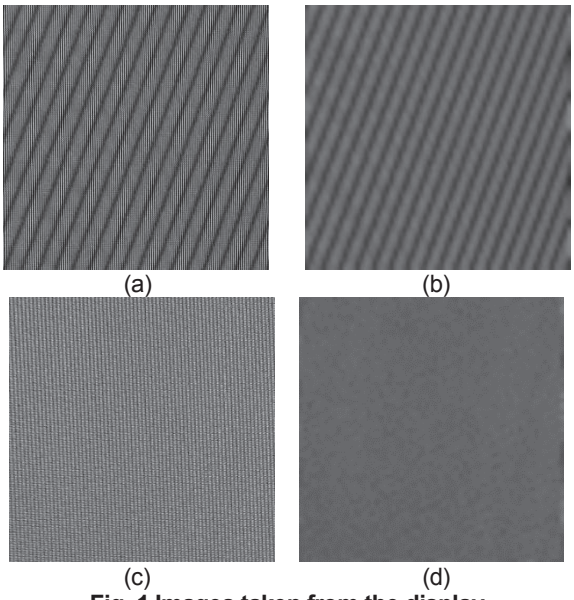
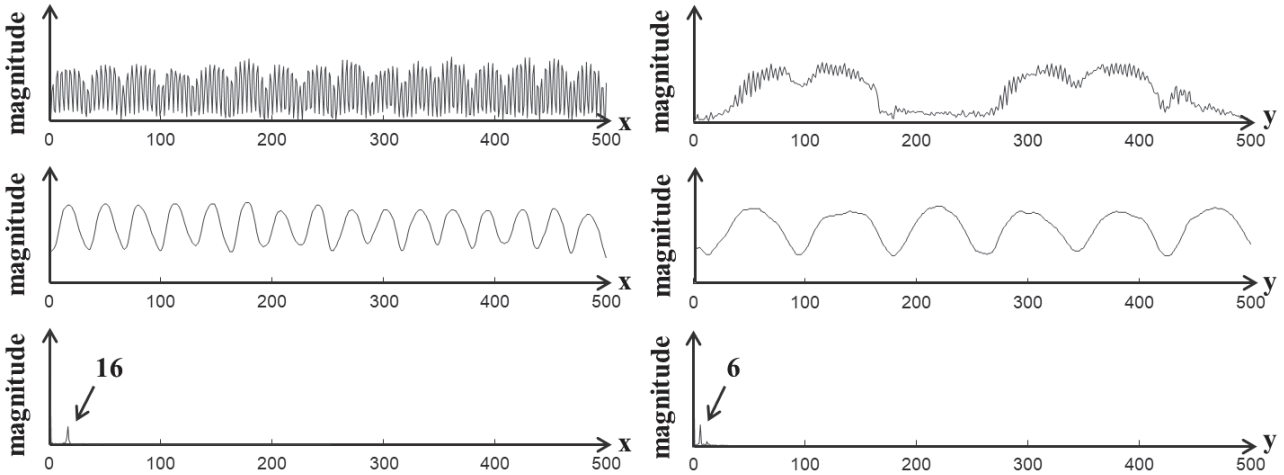


Fig. 1 Images taken from the display

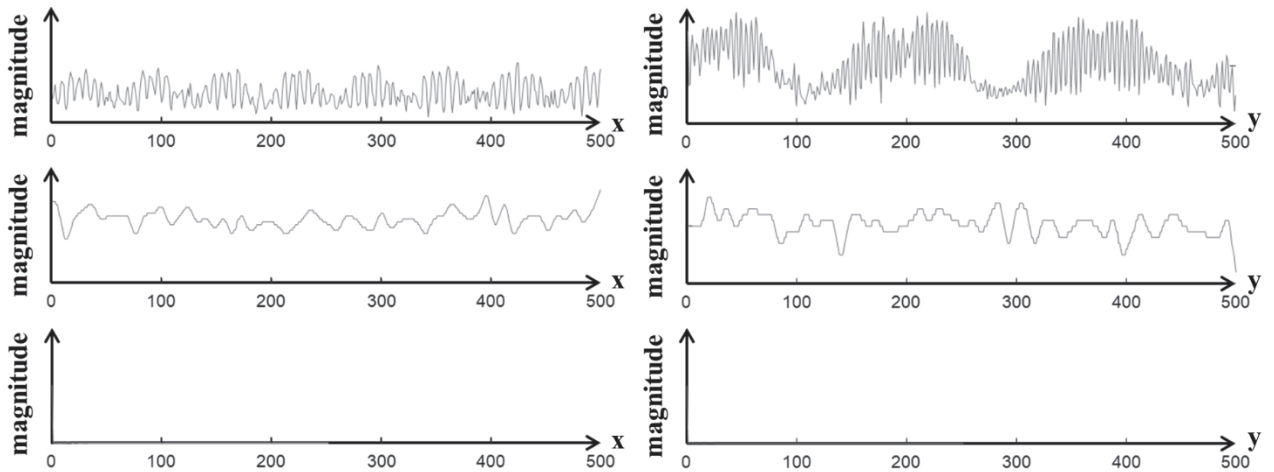
(a) and (c) are the original images, and (b) and (d) are the processed images. (a) and (b) are the images with moiré pattern, and (c) and (d) are the images without moiré pattern.



(a) (b)

Fig. 2 Graphs for each line on the x-axis and y-axis in an image with moiré pattern

(a) represents the graphs for the line on the x-axis and (b) shows the graphs for the line on the y-axis. The first graph is the value of a line extracted from the original image, second is the one from the processed image and the last represents the value of Fourier transform, respectively.



(a) (b)

Fig. 3 Graphs for each line on the x-axis and y-axis in an image without moiré pattern

3 EXPERIMENTAL RESULTS

With the image of the moiré pattern from the display, a line is extracted from the x-axis and y-axis, respectively. The extracted lines are used to calculate the frequency, period, and angle of the pattern. Figure 1(a) shows a grayscale image taken from the display and Fig. 1(b) shows a processed image. The image was processed due to the difficulty of calculating the period of the pattern in the original image. Comparing the first graph and the second graph in Fig. 2(b), the second graph can easily examine the period of the pattern.

A line from the processed image is converted using Fourier transform, decomposing into a sum of periodic functions with varying frequencies. As shown in the last graph of Fig. 2(a), the x-axis consists of 16 cycles, which matches the number of cycles in the second graph. Figure 2(b) represents that the y-axis consists of 6 cycles. If the moiré pattern does not exist like in Fig. 1(c) and (d), the cycle is not clearly detected. Since the frequency does not appear in Fourier transform either, the last graphs in Fig. 3(a) and (b) do not have any specific point to indicate the presence of the frequency.

The angle of the moiré pattern can be calculated by the period of the x-axis and y-axis as shown in Fig. 4. With the example of Fig. 2, the period of the x-axis is 1/16 and the y-axis is 1/6 which indicates that $tan\theta$ is 2.67.

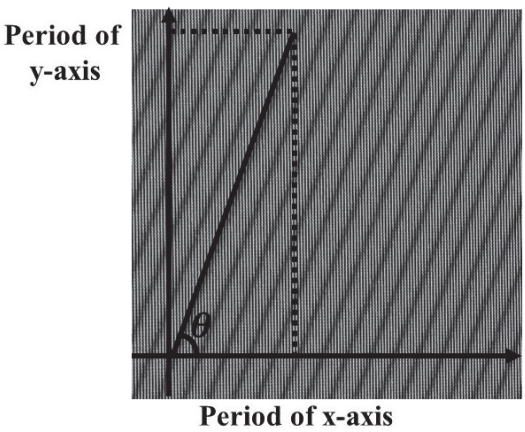


Fig. 4 Measurement of the angle of moiré pattern

4 CONCLUSIONS

With the emergence of auto-stereoscopic 3D multi-view display, the moiré artifact often appears when the pixel grid and the lenticular lens overlaps. The moiré has to be measured and the 3D parameters need to be changed to prevent eye degradation when watching 3D displays.

Therefore, we have proposed a measurement algorithm of moiré artifact for 3D displays using a Fourier transform. With the captured 3D moiré image, a line is extracted from the x-axis and y-axis, respectively. The frequency, period, and angle of the pattern are calculated by using Fourier transform to these lines. Applying the algorithm proposed in this study will help in the manufacture of 3D displays and can be applied to the 3D display measuring equipment.

5 ACKNOWLEDGEMENT

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