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Design of Zigzag Staggered Barrier for Autostereoscopic Display

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Abstract: Parallax barrier based autostereoscopic display is usually impaired by moire fringe and crosstalk. By using slanted parallax barrier, the moire fringes could be obviously eliminated, but often at the expense of serious image crosstalk. This paper presents a kind of zigzag staggered barrier which can reduce the moire fringe with little impact on the stereo viewing zones. The slits are divided into sections and the adjacent two jagged-edged sections are separated horizontally at a certain distance. This method can reduce the proportion of the perceived black matrix seen through the same slit, which increasing the brightness of the dark part of the moire fringe. In this way widen and weakened moire fringes are acquired. The simulated results show that the minimum perceived moire fringes' brightness decreases by 108.1% and the viewing zones decreases by 32.8% compared with the vertical parallax barrier. And it has higher practical value for autostereoscopic display.

Key words: Autostereoscopic display; Zigzag staggered barrier; Moire fringe; Crosstalk

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0 Introduction

Three-dimensional(3D) displays using special polarized glasses or shutter glasses are already reaching perfection. However, an ideal is to view stereo images without these special glasses[1]. The parallax barrier based method is probably the oldest known glass-less autostereoscopic technique and in such a system, parallax images are separated by the plurality of vertical stripe shaped slits[2-4]. In conventional vertical parallax barrier, slits are placed parallel to the pixel columns of the LCD (liquid crystal display) panel[5]. But moire fringes occur between the slits and the black matrix, which appear to be vertical stripes gradually changing between black and white. The fringes cause serious vision disturbance. And by using slanted parallax barrier, the moire fringes could be obviously eliminated, but often at the expense of serious image crosstalk[6]. This paper presents a kind of zigzag staggered barrier whose slits are jagged-edged and staggered horizontally. The method could lighten the moire fringes and has little impact on the stereo viewing zone.

1 Moire fringe and crosstalk principle of the parallax barrier

Fig. 1 illustrates the principle of autostereoscopic display based on a LCD panel and a vertical parallax barrier, where the parameters are given in terms of u, the distance of the eyes (typically 6.5 cm), s, the best viewing distance (typically 60～70 cm in our experiments), d, the distance between the barrier and the LCD panel, c, the

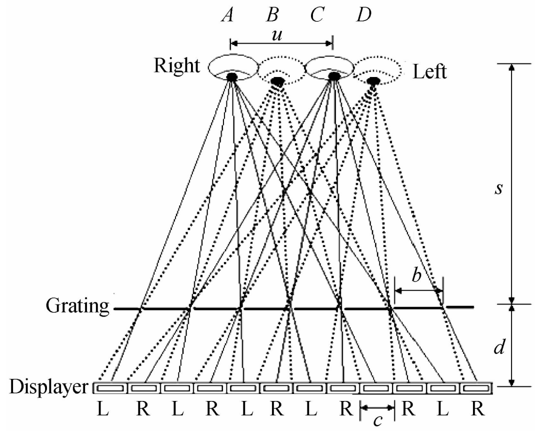

Fig. 1 The principle of autostereoscopic display based on a vertical parallax barrier and a LCD panel

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width of one display pixel, b, the period width of the barrier[7]. For two-view 3D displays, the relationship between these parameters could be expressed by

$$b=2c-\frac{2c^2}{u+c}$$

$$d=\frac{sc}{u}$$

Odd and even columns of the LCD panel are separated through the minute apertures and observed respectively by left(position C) and right (position A) eye. Hence two-view 3D display system is established by vertical parallax barrier, whose period is about twice of the pixel width[8-9]. The panel used in our experiments was a 14.5-inch LG . Philips LCD panel with a pixel array of 1 024×768 and pixel size of 279 μm×279 μm (i. e. , 93 μm×277 μm red, green, and blue sub pixels), and the horizontal black matrix is about 20 μm wide.

Serious moire fringes and limited viewing zones are two main problems for such a parallax barrier based system. When the eyes deviate horizontally from the proper viewing position(right eye at position B and left eye at position D, for example), the viewer will catch sight of the black matrix through the slits and the whole screen looks dark. The moire fringes will be obviously perceived especially when the viewer comes closer to the panel, which could be evaluated with their brightness and width. The viewing zones are the positions with low crosstalk, where both eyes observe their own images. The effect of crosstalk is mainly related to the width of the slits and large crosstalk will greatly limit viewing zones[10-12].

2 The design and simulation of zigzag staggered barrier

For reducing the effect of the moire fringes, a kind of zigzag staggered barrier is proposed in this paper. Fig. 2(a) shows the conventional vertical parallax barrier, the vertically staggered parallax barrier and the proposed zigzag staggered barrier, from left to right. The width of one slit is 25 μm for vertical parallax barrier. The slits of the vertically staggered barrier are segmented at the half of the pixel height. The separated distance of two adjacent segments is 10 μm and thus the whole width of one slit is 40 μm. The proposed zigzag staggered barrier which is jagged-edged. The width of the slit is 70 μm, which is 2.8 and 1.75 times of that of the other two.

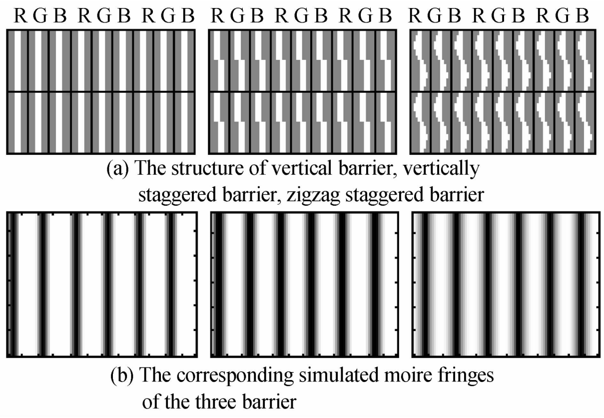


Fig. 2 The structure of vertical barrier, vertically staggered barrier, zigzag staggered barrier and the corresponding simulated moire fringes

The Moire fringes could be valued by the properties of the slits. The design of the staggered barrier is aiming at avoiding the alignment of the vertical slits. In other words, not all of the black matrix in the same column could be seen at the same time in such a system. As a result, the moire fringes are visibly weakened. To be specific, the aperture area of the slits is the same for these barriers and thus the number of the pixels which constituting the moire fringes are surely equal. In order to acquire weak moire fringes, the slits of the barriers should be as wide as possible, while the extra crosstalk will come out at the same time. We propose the zigzag staggered barrier, whose slits is wider than the other two and then the moire fringes are the most weak. The crosstalk of the proposed barrier is induced mainly by the jagged-edged projection between adjacent pixels, which is obviously slight than rectangular projection in the vertically staggered slits.

In our experiments for simulating the moire fringes, the displayed image is entirely white. The sum of the visible pixel values is defined as perceived brightness. Fig. 2(b) shows the simulated moire fringes of the three barriers viewing 30cm away from the panel. Obviously the moire fringes of the zigzag staggered barrier are the most wide and weak. The simulated brightness curves are shown in Fig. 3. The peak of the curves represents the bright part of the moire fringes where the viewer perceives the luminescent area of the display pixels. While the trough of the curve denotes the dark part of the moire fringes and the viewer perceives the black matrix area.

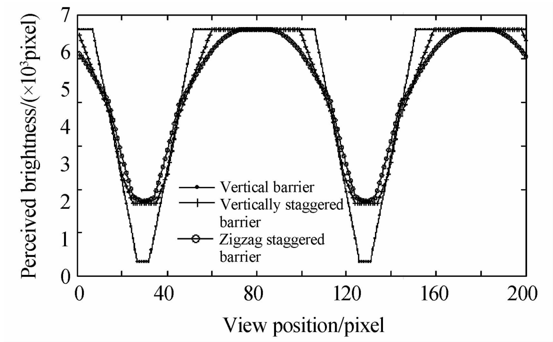


Fig. 3 The moire fringe simulation brightness curve of vertical barrier, vertically staggered barrier and zigzag staggered barrier

From the trough of the curve, it could be seen that the minimum perceived brightness of the vertical parallax barrier、vertical staggered parallax barrier and zigzag staggered barrier are 1 330, 2 665 and 2 768, respectively. And the dark part of the moire fringes are 43 μm, 59 μm and 75 μm wide, respectively. We can come to a conclusion that the moire fringes of the vertical parallax barrier is the most dark and narrow, resulting in badly visual effect. While the moire fringes of the zigzag staggered barrier is the most weak and wide, the minimum perceived brightness of which decreases by 108. 1% and 3. 9%, and the width raises by 74. 4% and 27. 1% compared with the vertical parallax barrier and the vertical staggered parallax barrier. Obviously the proposed barrier has the best visual effect.

When simulating the viewing zones, we set odd and even columns of LCD pixels to be black and white respectively. The black and white regions are examined for determining the viewing zones. Stereo degree is defined as min(LL, LR)/max(LL, LR), where LL and LR are the perceived brightness by left and right eye. Under a certain stereo degree, large viewing zones are acquired if the area of black and white sharply contrasted, and vice versa. Fig. 4 shows the simulated viewing zones of the three barriers viewing 30cm away from the panel. Curve fitting method is applied in stereo degree computing. And the viewing zones of the vertical parallax barrier, vertical staggered parallax barrier and zigzag staggered barrier are 58 μm, 47 μm and 39 μm when the stereo degree is 11. 5. We could draw the conclusion that the viewing zones of the proposed method decreases by 32. 8% compared to the vertical parallax barrier.

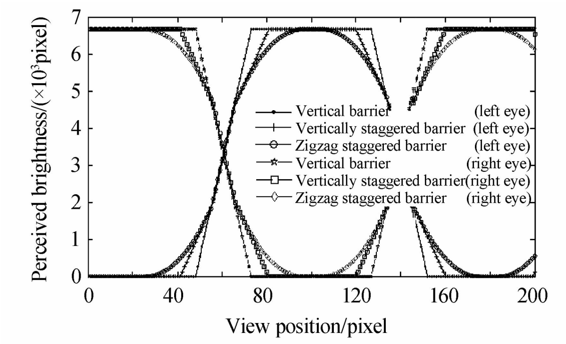


Fig. 4 The view zone simulation curve of vertical barrier, vertically staggered barrier and zigzag staggered barrier

Stereo displays is fabricated in our experiments. It is composed of a 14. 5-inch LCD panel and the corresponding parallax barriers. The barriers are attached to the surface of the panel and two-view stereo displays are realized. The results are measured by Canon digital camera about 30 cm away from the panel.

Fig. 5 shows the measured moire fringes when the displayed image is entirely white. In order to quantifying the three figures, automatic threshold segmentation is applied and the moire fringes are extracted. The width of the three moire fringes are about 6,23 and 16 pixels, and the peak value of them are 161,110 and 124. It could be seen that the moire fringes of the zigzag staggered barrier are more wide and weak than the vertically aligned barrier, but still more significant than then slanted barrier.

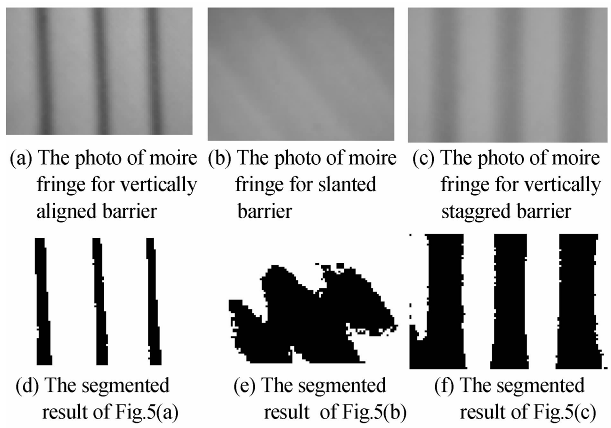
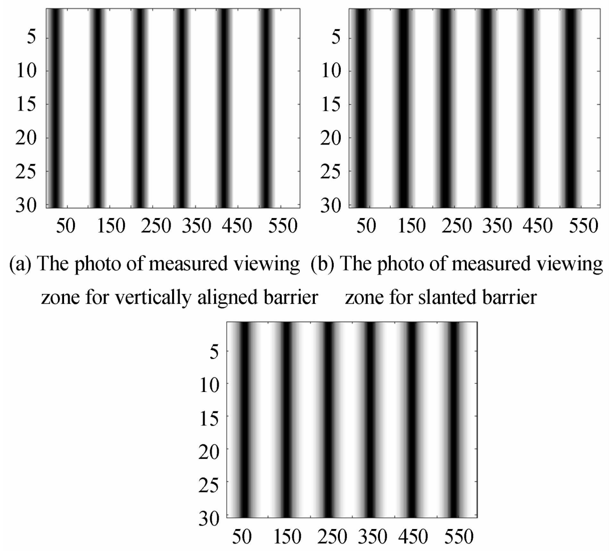


Fig. 5 The moire fringe images of vertically aligned barrier, slanted barrier and vertically staggered barrier

Fig. 6 shows the measured viewing zones when odd and even columns of LCD pixels are set to black and white respectively. The results demonstrate that the vertical parallax barrier leads to large viewing zones owing to narrow transitional region . While the viewing zones of the zigzag



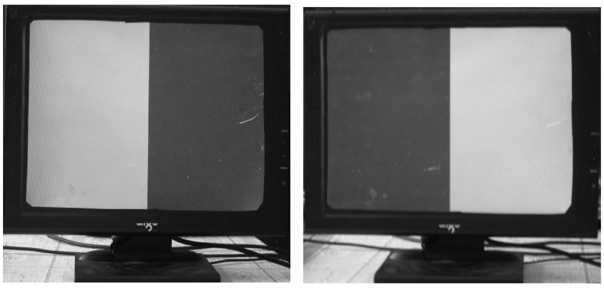
(a) The photo of measured viewing zone for vertically aligned barrier (b) The photo of measured viewing zone for slanted barrier

(c) The photo of measured viewing zone for vertically staggred barrier

Fig. 6　The measured viewing zone images of vertically aligned barrier, slanted barrier and vertically staggered barrier

staggered barrier is the most narrow due to the large transitional region.

For testing the stereo effect of the zigzag staggered barrier, different images for left and right eye are displayed. Fig. 7 shows the measured result (Canon digital camera, about 30 cm away from the panel). The images could be distinguished clearly which indicates high stereo degree.



(a) The photo of left eye　(b) The photo of right eye

Fig. 7　The photo of prototype

3 Conclusion

In conclusion, the moire fringes in conventional vertical parallax barrier based autostereoscopic display are remarkable. Zigzag staggered barrier method is proposed in this paper, which leading to compromising moire fringes and viewing zones. The design of jagged-edged slits further decreases the brightness of the moire fringe and also widens them. This method is proved to be effective by the simulated and measured results.

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自由立体显示器中锯齿状交错狭缝光栅的设计

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摘　要：光栅式自由立体显示由于易存在莫尔条纹和串扰的问题而影响其显示效果．利用斜光栅可减轻莫尔条纹但增加了视点间的串扰．本文提出一种减轻莫尔条纹的光栅设计方法，同时对可视区域影响较小．设计中对光栅进行分段，并将相邻两段狭缝错开一定距离．该方法能减小通过同一狭缝看到两相邻子像素之间的黑条的比例，获得较宽且较淡的莫尔条纹，从而减轻了视觉干扰．仿真结果表明该光栅相比传统垂直光栅，莫尔条纹亮度下降了 108.1%，而可视区域仅减小 32.8%，具有较高的实用价值．

关键词：自由立体显示；锯齿状交错狭缝光栅；莫尔条纹；串扰