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自由立体显示器倾斜锯齿交错狭缝光栅的设计

黄炳乐[1,2],郭太良[1],姚剑敏[1]
(1 福州大学 物理与信息工程学院,福州 350002)
(2 福建船政交通职业学院 信息工程系,福州 350007)

摘 要:针对光栅型自由立体显示方案易存在串扰和莫尔条纹的问题,提出一种莫尔条纹和可视区域均在可接受范围内的倾斜锯齿交错光栅设计方法,该方法在斜光栅结构基础上以一个像素高度的一半为单位对光栅进行分段,将相邻两段狭缝用对称三角形狭缝代替.该结构与斜光栅相比,减少了通过同一狭缝看到相邻子像素而产生的相互串扰,即减小了斜光栅存在的视点间的串扰,扩大了可视区域范围.仿真及实测结果表明倾斜锯齿交错光栅比斜光栅可视区域增加了 25%,而莫尔条纹亮度只减少 4.5%,具有一定的实用价值.

关键词:自由立体显示;倾斜锯齿交错狭缝光栅;莫尔条纹;可视区域;串扰
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Design of Slanted Zigzag Staggered Barrier for Autostereoscopic Display

HUANG Bing-le[1,2], GUO Tai-liang[1], YAO Jian-min[1]
(1 *College of Physics and Information Engineering, Fuzhou University, Fuzhou* 350002, *China*)
(2 *Information Engineering Department, Fujian Chuanzheng Communications College, Fuzhou* 350007, *China*)

Abstract: In order to eliminate the Moiré fringe and crosstalk existed in parallax barrier based autostereoscopic display, a new design of slanted zigzag staggered parallax barrier was presented for autostereoscopic display. The slits were divided into sections at half the height of a pixel and the adjacent two sections were symmetrical triangles based on slanted barrier. This method can decrease the probability of the perceived adjoining sub-pixel seen through the same slit when compared with the slanted barrier, thererfore, crosstalk can be reduced and the field of viewing zone can be extended. The simulated and measured results show that the proposed method can increase the viewing zone by 25% more than that of slanted barriers with a decrease of only 4.5% of the Moiré fringe. And it has higher practical value for autostereoscopic display.

Key words: Autostereoscopic display; Slanted zigzag staggered barrier; Moiré fringe; Viewing area; Crosstalk
OCIS Codes: 120.2040; 160.3710; 110.6880; 350.2770

0 Introduction

Stereoscopic display technology has become the key research fields of science and technology because of its superior performance, its realization methods can be divided into two kinds, one kind of Three-dimensional (3D) displays is using special polarized glasses or shutter glasses, and the other kind is the well known glass-less autostereoscopic technique[1,2]. The slit barrier for autostereoscopic display is the simplest structure of the second kind, and it is the relatively low cost of design, having a broad market value. So far,

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First author: HUANG Bing-le (1982—), male, lecturer, M. S. degree, mainly focuses on information display technology. Email: 22826639@qq.com
Responsible author (Corresponding author): GUO Tai-liang (1963—), male, researcher, Ph. D. degree, mainly focuses on FED and information display technology. Email: gtl_fzu@hotmail.com
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there are a few universities and research institutions where the researchers make use of the technology to develop a few experimental products[3-4]. WANG Pei-shun proposed design of vertically staggered barrier for autostereoscopic display[5], YAO Jian-min proposed design of zigzag staggered barrier for autostereoscopic display[6], but the viewing zone is obviously reduced in these methods.

In conventional vertical parallax barrier, slits are placed parallel to the pixel columns of the Liquid Crystal Display (LCD) panel[7]. But Moiré fringes occur between the slits and the black matrix, which appear to be vertical stripes gradually changing between black and white[8]. The fringes cause serious vision disturbance. By using slanted parallax barrier, the Moiré fringes could be obviously eliminated, but most at the expense of serious image crosstalk[9]. This paper presents a kind of slanted zigzag staggered barrier whose slits are symmetrical triangles and staggered horizontally. The method could increase the stereo viewing zone and has little impact on the Moiré fringes.

1 The principle of the Moiré fringes and the crosstalk

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 65mm), s, the best viewing distance (typically 200-220cm in our experiments), d, the distance between the barrier and the LCD panel, c, the width of one display pixel, b, the period width of the barrier. 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) eyes. Therefore two-view 3D display system is established by vertical parallax barrier, whose period is about twice of the pixel width[10]. The panel used in our experiments was a 24-inch LG. Philips LCD panel with a pixel array of 1920 ×1080 and pixel size of 279μm×279μm (i. e., 93μm× 277μm red, green, and blue sub pixels), and the horizontal black matrix is about 20μm wide. For two-view 3D displays, the relationship between these parameters could be expressed by[11]

$$b=2c-\frac{2c^2}{u+c} \tag{1}$$

$$d=\frac{sc}{u} \tag{2}$$

In order to balance the display area and luminance, generally, the width of the slits and the black strips is best to be 1:6 in parallax barrier. The typical structure of the barriers is composed of the vertically aligned barrier and the slanted barrier, the slits of the vertically aligned barrier and the pixels in the column direction are parallel, and the intersection angle for the slanted barrier is arctan(1/3)[12].

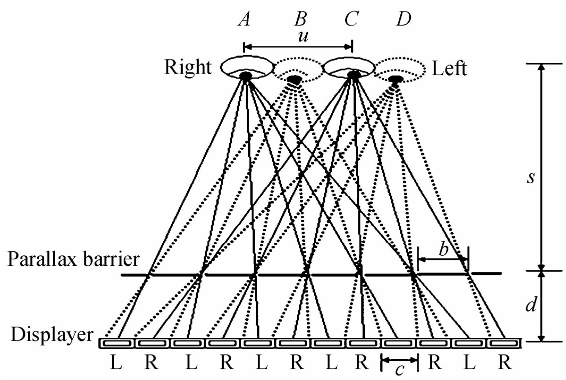

Fig. 1 The principle of autostereoscopic display based on parallax barrier

The slits and the black strip between the sub pixels are arranged periodicity. 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 Moiré fringes will be obviously perceived especially when the viewer comes closer to the panel, which could be evaluated with their brightness and width. The luminance and width of the black strip that the viewer has seen decide the influence of the Moiré fringes[13].

The phenomenon that both eyes can see each other images is called image crosstalk. Stereo perception can not form, where the eye is in the location of the crosstalk zones. The effect of crosstalk is mainly related to the width of the slits and large crosstalk will greatly limit viewing zones[14].

2 The design and simulation of the slanted zigzag staggered barrier

The slanted barrier is oblique strip, so the adjacent sub pixels can not be strictly separated by it. The figure is showed in Fig. 2 (a). In order to avoid the problem of the crosstalk between the viewing points, the paper proposes a new method of the slanted zigzag staggered barrier; the design method is showed in Fig. 2 (b). The four lines A_1C_1、B_1D_1、AC and BD are parallel. So the inclined angle of the proposed barrier is as same as that of the slanted barrier, because the inclined angle could influence the Moiré fringes. In order to satisfy the same area of slits, the distance between A_1C_1 and B_1D_1 is the 1/3 of the barrier's period. The slit is separated into two partitions in the half height of the sub pixel.

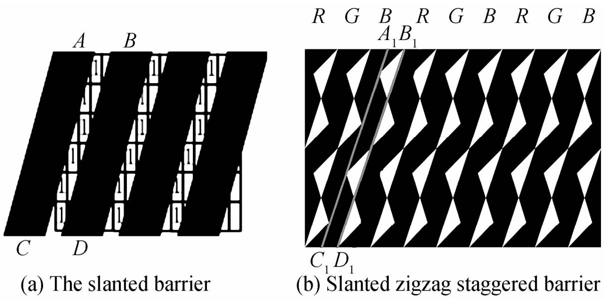

Fig. 2 The structure of slanted barrier

2.1 The Moiré fringes simulation of the proposed method

In the experiment, we take the Moiré fringes that occur when the eyes are near the display for example. The width of the lighting sub pixels that are seen through the slits is defined as the viewing luminance[15], and the stereo pair image displayed on the screen is wholly white. The period of the vertical and slanted barrier is 185.7μm, and the width of the slits is 30μm. Fig. 3 (a) is the Moiré fringes for the vertically aligned barrier, fig. 3 (b) is for the slanted barrier. We can see that the Moiré fringes for the vertically aligned barrier are more obvious. The Moiré fringes of the proposed showed in Fig. 3(c) is weaker than that in the Fig. 3(a), and is a little more obvious than that in the Fig. 3(b), but it is acceptable.

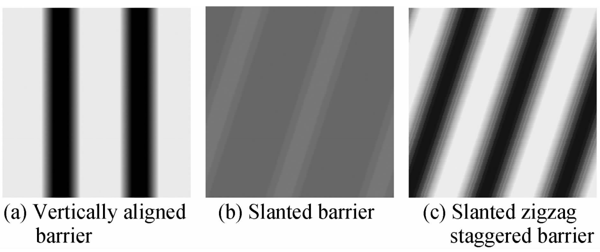

Fig. 3 The Moiré fringe simulation results of vertically aligned barrier, slanted barrier and slanted zigzag staggered barrier

The simulation curve of the vertically aligned, the slanted and the proposed barrier is showed in the Fig. 4. When we see the light region of sub pixels through the slits, set the width of the slits as the viewing luminance, and it is 30μm of the most viewing luminance. When we see the black matrix through the slits, the luminance reduces.

The luminance is between 22μm and 24μm for the slanted barrier in the simulation figure of the Fig. 4, the luminance is between 21μm and 25μm for the proposed method. The minimum luminance of the proposed method is 4.5% less than that of the slanted barrier. The minimum luminance is 10μm for the vertically aligned barrier, it is one third of the maximum luminance, so the Moiré fringes for the slanted is weakest, the one for the proposed method is the second weakest and the one for the vertically aligned is most obvious.

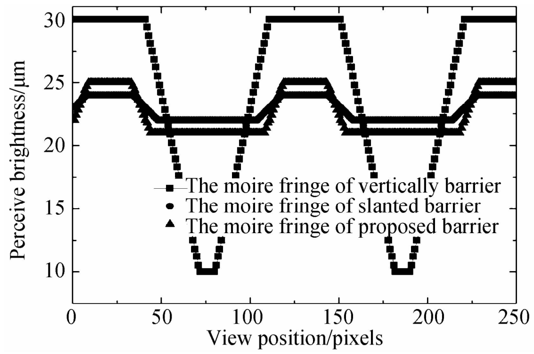

Fig. 4 The Moiré fringe simulation curve of vertically aligned barrier, slanted barrier and proposed barrier

2.2 The viewing zone simulation of the proposed method

Take the crosstalk viewing display near for example. We set odd and even columns of LCD pixels to be black and white respectively. The transitional region between the black and white determines the level of crosstalk and the size of the viewing zone. Fig. 5 (a) and (b) are the simulation figure of the viewing zone for vertically parallax barrier and the slanted barrier respectively. Their period is obviously equal, yet the transitional region between the black and white for the vertically parallax barrier is narrower than that of slanted barrier, and the contrast between the black and white zones is sharp. So the crosstalk for the vertically barrier is smaller than that for the slanted barrier, and the viewing zone is larger than that for the slanted barrier.

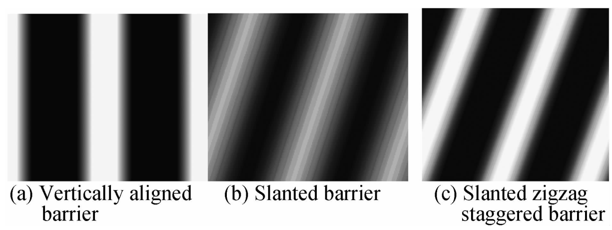

Fig. 5 The viewing area simulation results of vertically aligned barrier, slanted barrier and slanted staggered barrier

Fig. 5(c) is the simulation figure of the viewing zone for slanted zigzag staggered barrier, the viewing zone is almost equal to that of Fig. 5 (a) for the vertically aligned barrier, and is larger than that of Fig. 5(b) for slanted barrier.

Fig. 6 is the simulation figure of the viewing zone for the vertically aligned barrier, slanted barrier and slanted zigzag staggered barrier. If the crosstalk disappears, in theory the duty ratio for the curve is 50% of the square wave. Suppose the viewing zone is ±10μm region of the most and least of the black & white image for both eyes. In the figure, we can see that the viewing and crosstalk zone for slanted zigzag barrier is 60μm and 40μm respectively, the viewing zone is 60% of the whole viewing point region. The viewing and crosstalk zone for the slanted zigzag staggered barrier is 35μm and 65μm respectively, the viewing zone is 35% of the whole viewing point region. So the viewing zone for the slanted zigzag staggered barrier is larger by 25% than that for the slanted barrier, and it is 1.71 times of that for the slanted barrier.

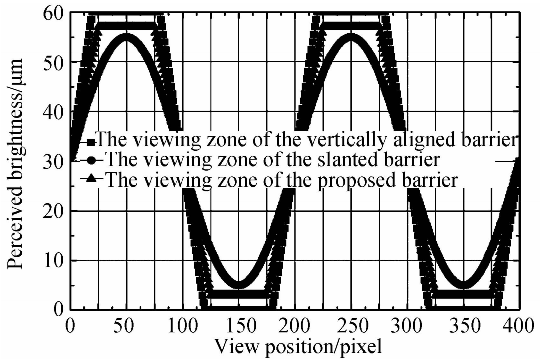

Fig. 6 The viewing zone simulation curve of vertically aligned barrier, slanted barrier and proposed barrier

3 Experimental results and analysis

The autostereoscopic display consists of a 24-inch LCD panel and the barrier in our experiments, the barrier is attached to the glass of 3 mm thickness, and this glass is covered over LCD panel. The period of the barrier is equal to the width of the two sub-pixels, consisting two viewing points display. We photograph the image by using Canon digital camera, about 210 cm away from the panel.

3.1 The photo of the Moiré fringes

Set the image of both eyes into white color when testing Moiré fringe. Fig. 7 is the photo of the Moiré fringe for the vertically aligned barrier, the slanted barrier and the proposed barrier.

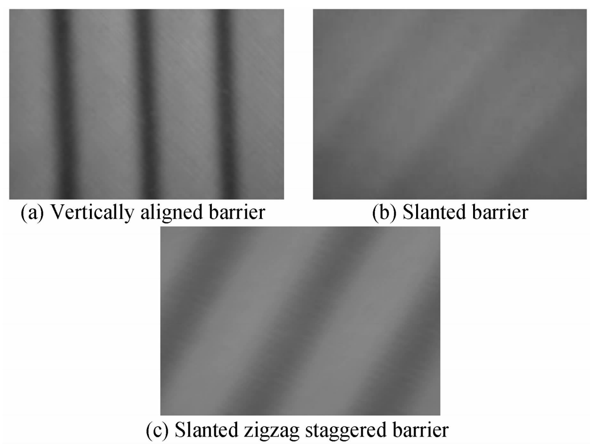

Fig. 7 The Moiré fringe images of vertically aligned barrier, slanted barrier and slanted zigzag staggered barrier

The Moiré fringe for the vertically aligned barrier is the most obvious than the other two in the images above, the value of the fringe's gray is very low. The value of the Moiré fringe's gray for the slanted barrier is higher, so the Moiré fringe is not obvious. The result that the Moiré fringe for the slanted barrier and the slanted zigzag staggered barrier is the weakest and weaker conforms to the result of the simulation. But also the Moiré fringe for the slanted zigzag barrier is acceptable.

3.2 The photo of the viewing zone

Set the images for the left and right eye into the whole black and white images when testing the image crosstalk for both eyes. Fig. 8 is the viewing zones of the figure photographed for the vertically aligned barrier, the slanted barrier and the slanted zigzag staggered barrier.

The transitional region of the black and white for the vertically aligned barrier is smaller, so the viewing zone for it is the largest. The transitional region of the black and white for the slanted zigzag staggered barrier is much smaller than that for the slanted barrier, in other words, the crosstalk's region is much smaller, and the viewing zone is much larger. The transitional region for the slanted is much large, and it almost occupy the whole period, so the crosstalk's region for it is largest and the viewing zone is smallest. Therefore, the viewing zone for the slanted zigzag staggered barrier is much larger than that for the slanted barrier. The conclusion conforms to the result of the simulation.

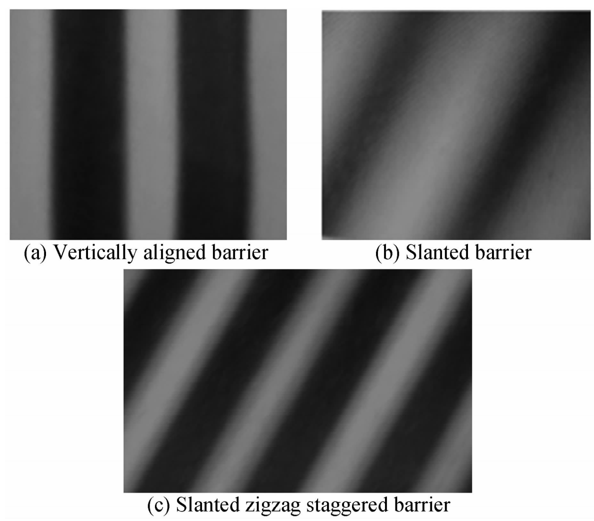

Fig. 8 The viewing area images of vertically aligned barrier, slanted barrier and slanted zigzag staggered barrier

3.3 The photo of the prototype

In order to test the performance of the slanted zigzag staggered barrier, we photographed the images of the prototype showed in the Fig. 9 twice by using the same camera. The image of the left eye is composed of white color in the right half of the screen and black color in the left half of the screen. The image of the right eye is composed of black color in the right half of the screen and white color in the left half of the screen. The contrast of the black and white is sharp for both eyes in the figure below.

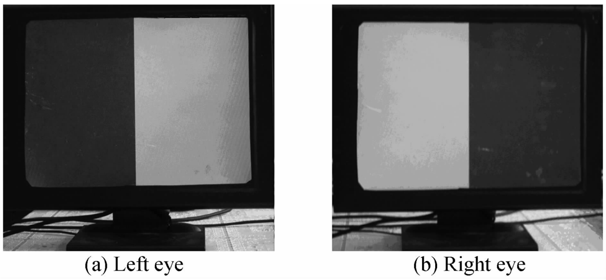

Fig. 9 The photo of prototype

4 Conclusion

In conclusion, among the designs of the barrier for autostereoscopic display, the Moiré fringes were the most obviously, and the viewing zones for the slanted barrier were much small, so we proposed a design of the slanted zigzag staggered barrier, and the design could obviously increase the viewing zones and the effect for the Moiré fringes were relatively small. Finally, the photo was displayed in the prototype and the results demonstrated the effectiveness of this design.

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