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Ghost Image Reduction in 3d Images by Multi-Zone Digital Crosstalk Reduction

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***Abstract*—** In commercial 3D display system, the optical crosstalk is a major issue which produces ghost image. Crosstalk is a critical factor which determines the image quality of displays. A digital image processing technique called Multi-Zone digital crosstalk reduction has been used to reduce the crosstalk in 3D displays. Multi-zone digital crosstalk reduction is an advanced technique that uses the software approach as well as the pixel structure of the display. It reduces the crosstalk by modifying the output gray level of the image. The pixel layout of a patterned retarder display is taken and in order to apply multi zone digital crosstalk reduction to a patterned retarder display a 2 data line and 1 gate line (2D1G) panel is used. For the multi view systems where the viewing angle is high the crosstalk is much higher and it reduces the 3D image quality. By applying multi zone digital crosstalk reduction to such systems the crosstalk will be reduced while maintaining the luminance of the image without any extra devices.

Index Terms— Crosstalk suppression, image processing, patterned retarder 3D display, 3D display.

I. INTRODUCTION

Three dimensional (3D) systems is on the verge of constant development in scientific as well as the entertainment community in recent years. With the progress of the times, the needs of a better 3D vision have been steadily increasing. The 3D system, including stereoscopic and auto-stereoscopic3D system can provide 3D images on a flat panel. According to the method of 3D perception in commercial 3D technology, the most common method is to use binocular parallax. Nevertheless, the crosstalk issues in 3D technologies still need to be further addressed. The images with Crosstalk will substantially lower the image quality, and cause uncomfortable feeling. Moreover, the ghost images will even disable the ability of the human brain to fuse the two images together. For these reasons, decreasing the crosstalk in 3D systems is an essential and highly expected task. There are several methods have been proposed to reduce crosstalk but the low brightness and extra devices are still unsolved problems in these methods.

II. MULTI-ZONE DIGITAL CROSSTALK REDUCTION (MZ-DCR) METHOD

The MZ-DCR method controls the image signal based on the structure of a 3D display system to counteract the light leakage.In order to make it more comprehensible, in this paper, we will take the patterned retarder 3D display as an example. Furthermore the MZ-DCR method can also be applied to the auto stereoscopic display, for example, lenticular lens type 3D display or barrier type 3D display. To apply the MZ-DCR method to the patterned retarder 3Ddisplay, an individual zone controllable panel is required. The pixel layout of this multi-zone panel is shown in Fig. 2, compared with a regular panel. The number of zones of this particular panel is not restricted. In this paper, a 2D1G panel (with two zones) is used which divided the original sub-pixel of regular panel into main and sub regions. With its two data lines and one gate line architecture, the main and sub regions can be controlled individually. The inherent drawback of the patterned retarder display is depicted in Fig. 1. The crosstalk of this kind of display is mainly caused when watching the panel in large viewing angle, and is extremely sensitive to the vertical viewing angle. In some cases, even a slight movement of the user's head will largely affect the 3D image quality. The observer might receive part of light leakage which belongs to the other eye. When the user watches the 3D display in large vertical viewing angle, the light leakage will become larger and so does the crosstalk. At the right side of Fig. 1, the green region represents the area that the user perceived, and it will shift as the user deviates away from the previous viewing angle. From these

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figures, one can easily find out where the crosstalk comes from.

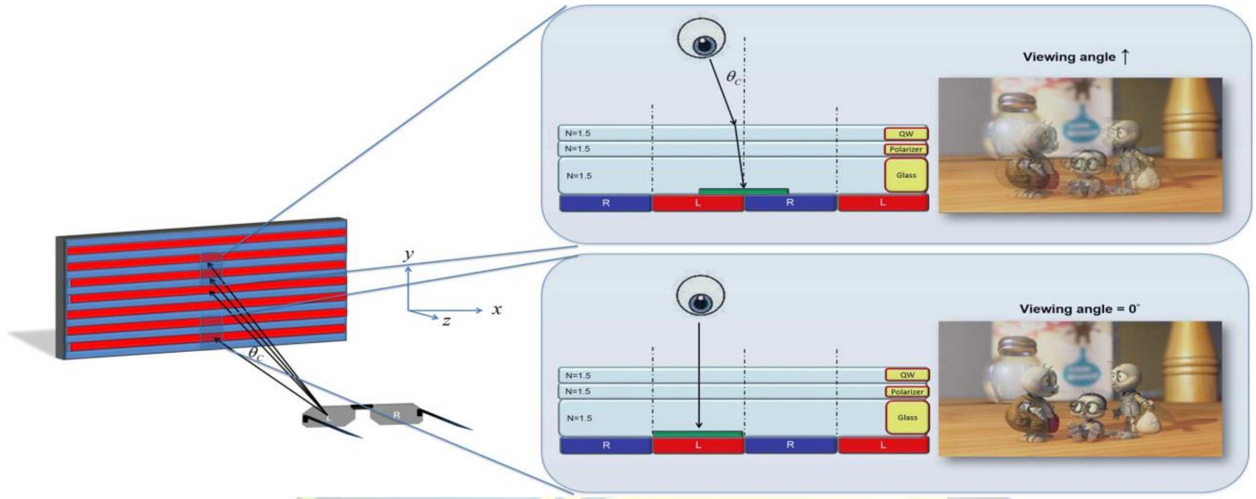

Fig. 1. User watches a patterned retarder display in vertical direction. The images at the right side show main components of the pattern retarder display and the corresponding images at different viewing angle.

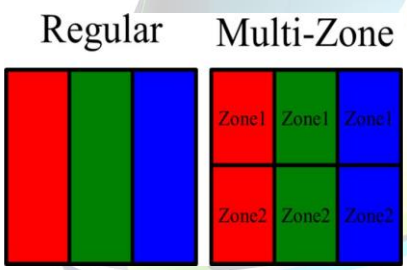

Fig. 2. Comparison of pixel layout of a regular panel and a 2D1G panel.

III. Principle Of Mz-Dcr

In display technology each pixel is represented by a sub pixel which has the colour components red, blue and green. Using the patterned retarder 2D1G panel each of the sub pixels can be divided into two zones called as the main region and sub region. The 3D display having the patterned retarder film has left image pixels and right image pixels. The left image pixels are positioned at odd pixel rows of the display, and the right image pixels are positioned at the other pixel rows or vice versa. In auto-stereoscopic display the left and right images are seen by the left and right eye respectively. Hence the original image can be split into two images namely left and right images. The main and sub regions of the left image is represented by $L_{main,i}$ and $L_{sub,i}$. Similarly the main and sub regions of the right image is represented by $R_{main,i}$ and $R_{sub,i}$. The gray levels of the adjacent pixels are taken for calculation inorder to reduce the crosstalk. The adjacent pixels of $R_{main,i}$ are R_i and L_{i+1} and the gray levels of these adjacent pixels are represented by $GL_{R,i}$ and $GL_{L,i+1}$ levels are represented by $GL_{R,i}$ and $GL_{L,i}$ respectively. Firstly the gray levels of $R_{main,i}$ and $L_{main,i}$ is checked whether they could compensate the original gray level to reduce crosstalk. The shared area or the common area is referred as the area where the pixels of right and left images interferes or mixes up leading to ghosting of images. If the gray level of the shared area can be replaced by taking the minimum of the adjacent pixels of both the right and left images separately then the original gray level of the image can be compensated. If the original gray level cannot be compensated by minimum gray level of adjacent pixels then the average gray level of the adjacent pixels are taken to compensate the original gray level. It is hard to decide whether the minimum of the adjacent pixels or their average will compensate the original gray level to reduce the crosstalk. Hence a judgment is used to determine it. The judgment formula for the right and left images are given below.

$$Judge_{R,i} = \frac{GL_{R,i}}{255} - \frac{\min(GL_{R,i}, GL_{L,i+1})}{255} \times \frac{A_{main,i}}{2A} - \frac{\min(GL_{R,i}, GL_{L,i})}{255} \times \frac{A_{main,i}}{2A} \quad (1)$$

$$Judge_{L,i} = \frac{GL_{L,i}}{255} - \frac{\min(GL_{R,i}, GL_{L,i})}{255} \times \frac{A_{main,i}}{2A} - \frac{\min(GL_{R,i-1}, GL_{L,i})}{255} \times \frac{A_{main,i}}{2A} \quad (2)$$

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If the judgment result for the right and left images are found to be less than or equal to zero then the minimum of the adjacent pixels can be used to compensate for the original gray level. It shows that the brightness of the original image can be maintained. And if the judgment result of the right and left images are found to be greater than zero then the average of the adjacent pixels of the right and left images are taken to compensate for the original gray level. It indicates that the brightness of the main region will be lesser than the brightness of the original image. Hence the average gray level of the adjacent pixels is taken to meet the deficiency of original image. The minimum and average gray level of the right image is represented by $min(GL_{R,i}, GL_{L,i+1})$ and $\frac{GL_{R,i} + GL_{L,i+1}}{2}$ .Similarly the minimum and average gray level of the left image is represented by $min(GL_{R,i}, GL_{L,i})$ and $\frac{GL_{R,i} + GL_{L,i}}{2}$. In an effective manner the main region will compensate for the original gray level. Likewise the gray levels of the sub region of left and right images are estimated. Once the gray level of the main region is found then it is easier to calculate the gray levels of the sub region such that it also compensates for the original gray level thereby greatly reducing the crosstalk by improving or maintaining the brightness of the original image. The gray levels of the sub region of left and right images are calculated by the formula given below.

$$R_{sub,i} = \left(GL_{R,i} - R_{main,i} \times \frac{A_{main,i}}{A}\right) \times \frac{A}{A_{sub}} \quad (3)$$

$$L_{sub,i} = \left(GL_{L,i} - L_{main,i} \times \frac{A_{main,i}}{A}\right) \times \frac{A}{A_{sub}} \quad (4)$$

Thus by comparing and compensating the gray level of main and sub region of the right and left image with the gray level of the original image the crosstalk is reduced and the brightness is maintained. The principle for MZ-DCR for the right and left images are shown in the figure. And the flowchart gives the modifying process.

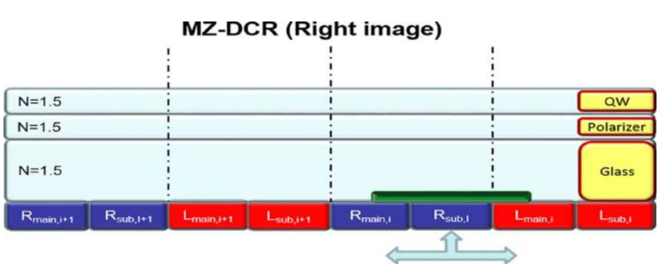

Fig. 3. Principle of MZ-DCR method in right image.

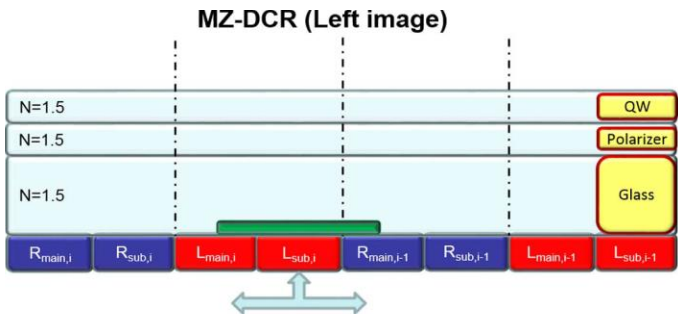

Fig. 4. Principle of MZ-DCR method in left image.

IV. EXPERIMENTAL RESULTS

In order to evaluate the improvement of the MZ-DCR method in patterned retarder 3D display, several simulated images of the MZ-DCR method were compared with the original image as shown in Fig. 5. These images were simulated by a simulation platform which was presented recently. This platform can simulate the light profile and optical crosstalk on the patterned retarder 3D display and show the perceived image of the user. In Fig. 5, a 2D1G patterned retarder 3D display was simulated and the area ratio of the sub region to main region is 2to 1. The original image at the left side of Fig. 5 means that the main region of the 2D1G panel is turned on. It is easy to perceive the difference between these two pictures, especially in the red circles. The light leakage in the image with MZ-DCR method is the same as the original one, yet the ghost phenomenon have been dramatically eliminated. Please note that, in the comparison, we did not use any instrument to measure the light profile. It is mainly because that the MZ-DCR method is armed to counteract the optical crosstalk, which means we cannot define how much crosstalk was improved and counteracted by measuring the light profile or intensity. As stated before, the idea of MZ-DCR method is to counter act the light leakage, but how much crosstalk could MZ-DCR method reduce? Actually, it depends on the gray level of each pixel, which means that the compensation ability of MZ-DCR method will vary as the output image changes. In here, we consider the worst case to demonstrate the limitation of MZ-DCR method. With a different area ratio between main region and sub region, the maximum angle, MZ-DCR method can completely counteract the crosstalk, is changed as depicted in Fig.6.The areas in blue color indicate the maximum gray level that the MZ-DCR method can successfully counteract in different viewing angle. From Fig. 6, we can find out that the ratio of the sub region decreases and main region become higher and the usable gray level would be extended instead. Thus we should appropriately adapt the suitable ratio of the main and sub pixels for different viewing conditions and scenarios. For example, when watching a 65-inch 3D display at a distance about 3 m, the ratio of 3 to 1 is sufficient for the user to perceive perfect 3D vision. However, if the viewing distance is close to 2 m, the ratio needs to be changed to 2 to 1. The image in the original design will be damaged when the viewing angle increased as stated before. By applying the DCR method, the crosstalk can be reduced in almost every viewing angle, but the over-reduced art if act at0 and crosstalk phenomenon at large view angle can still interfere the user to fuse stereo images. On the contrary, the proposed MZ-DCR method can successfully eliminate the crosstalk at the normal viewing condition. It not only completely removes the ghost phenomenon, but also maintains the luminance of the3D images when compared with DCR method. By applying the MZ-DCR method, generally, the viewing angle can be extended to 15 degree. However, the maximum extendable viewing angle of our proposed method actually varies in different images. It is highly related to the gray level of the original image as demonstrated in Fig. 6.In order to know how much the quality has been improved, we thus used the structural similarity (SSIM) index to measure the quality of the output image. The SSIM index measures the image quality based on an initial uncompressed or distortion free image as reference, and it has been proven to be consistent with the human eye perception. The higher score indicates that the output image is similar to the reference image. We took the original image at 0 degrees as reference and showed the SSIM score under each test image. From theses cores the proposed SDCR method has been proven to improve the image quality in every viewing angle. It also demonstrated that the output image maintained 0.99 scores at 15 degrees, while the original image only obtained 0.97 scores.

Fig. 5. Comparison of original image with image with MZ-DCR method

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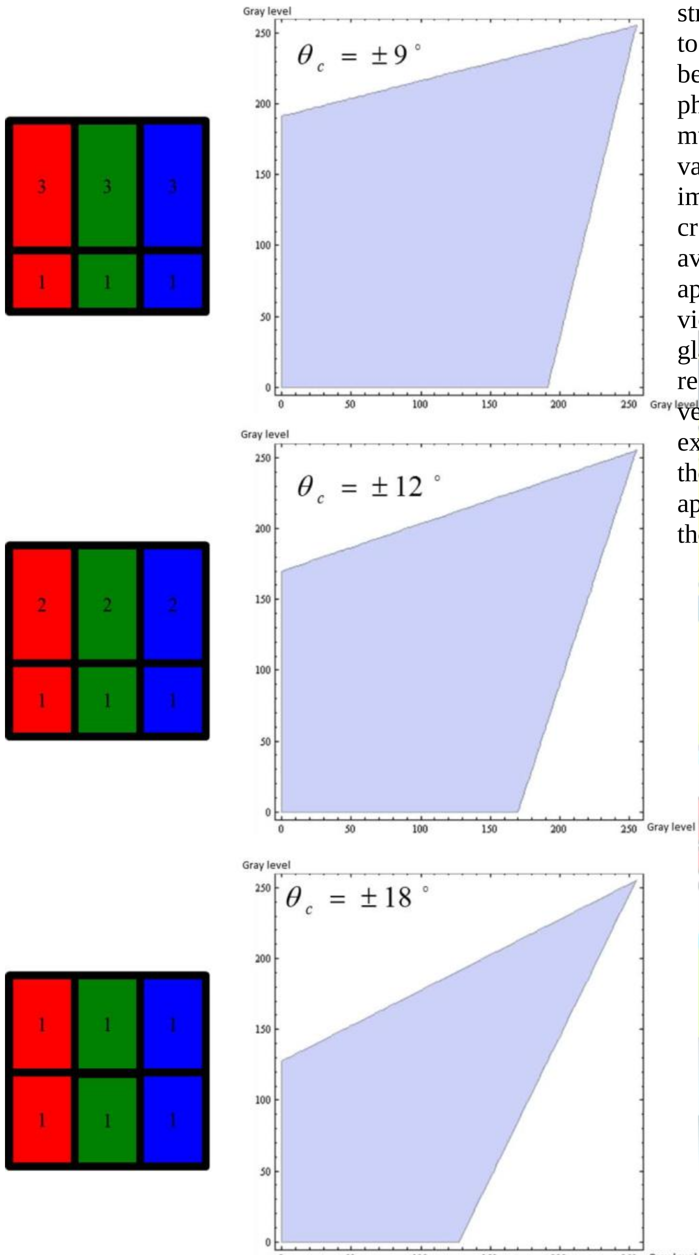

Fig. 6. Limitation of MZ-DCR method corresponding to the gray level of each pixel and the ratio between main region and sub region

V. Conclusion

The Multi-Zone Digital Crosstalk Reduction (MZ-DCR) method is thus used to remove the crosstalk from the images and improve the image quality. It utilizes the structure of an individual zone controllable multi-zone panel to counteract the light leakage. The MZ-DCR method has been proved to be successful in eliminating the ghost phenomenon under the normal viewing condition and also in multi view system while maintaining the luminance. By varying and modifying the gray level of the pixels of the image no extra hardware devices are required to reduce the crosstalk. The need for wearing 3D glasses is completely avoided by this new technology. This technology can be applied to stereoscopic display systems too and when the viewer views the image using the shutter glasses or polarized glasses the image quality is further improved. All the restrictions of 3D system have been overcome and it is a very effective software approach which does not require any extra devices to reduce the crosstalk. The advancements in the pixel structure of the panel also play an important role in applying this technique. Hence by applying this technique the viewing angle has been improved to 15 degrees.

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