MOIRÉ-FREE FULL PARALLAX HOLOSCOPIC 3D DISPLAY BASED ON CROSS-LENTICULAR

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Holoscopic imaging also known as Integral imaging is a promising 3D solution that mimics the imaging system of insects, such as the fly, utilizing a single camera, equipped with a large number of microlens array, to capture a scene, offering rich parallax information and enhanced 3D feeling without the need of wearing specific eyewear. Recently, initial developments are made for designing a full parallax holoscopic 3D display using parallax barriers which suffers low lighting throughput as the constructed 3D scene is a rather dim. Also a first attempt was made designing an omnidirectional holoscopic 3D display using cross-lenticular which introduces moiré effect. This paper proposes and presents a moiré-free full parallax holoscopic 3D display which offers omnidirectional motion parallax and complete 3D depth.

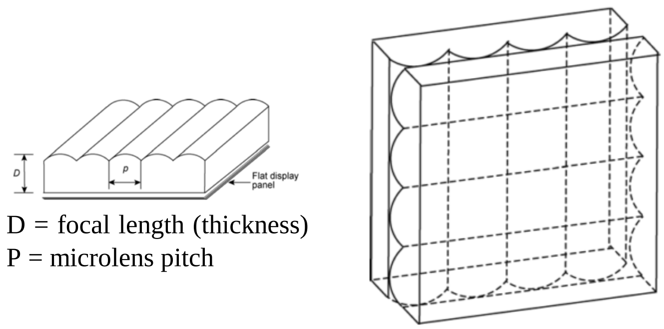
Index Terms— Holoscopic image, integral image, multiscopic, Autostereoscopic, 3D, Lenticular, 3D Display, omnidirectional, full parallax, motion parallax, 3D depth, moiré effect, cross-lenticular

1 INTRODUCTION

Holoscopic imaging [2] "Integral imaging" was first proposed by Lipmann [1] in 1908 that facilitates a single aperture lens for recording 3D depth. It constructs a true 3D scene in space and it does not have any side-effect such as motion sickness and eye-fatigue [2]. As a result, it is a promising way forward for future 3D imaging and display solution.

Recently, numbers of solution have been proposed for unidirectional autostereoscopic 3D display namely Multiview / Multiscopic [3]. The unidirectional 3D displays are widely available commercially in the market that are built with lenticular or parallax barriers technology [6][7][8] and offer one dimensional i.e. horizontal 3D depth and motion parallax. This technology also has its own challenges such as unbalance / unstandardized aspect pixel ratio, lighting, horizontal 3D resolution which were improved using pixel mapping [9][10][11] and directional back lighting techniques[12].

The full parallax autostereoscopic 3D display [13] attracts a great attention from both researchers and consumers. It offers complete 3D depth and motion parallax with standard pixel aspect ratio. However, the main problem is manufacturing a large size of spherical microlens lens array almost impossible due to its cost. An alternative solution was first proposed in 1998 using a cross-lenticular sheet [14], which is putting two lenticular sheets back-to-back as shown in Fig 1 (b). Fig 1 (a) illustrates structure of the lenticular sheet structure in which p represents the microlens pitch covers N number of pixels and D represent focal length (thickness) of the lenticular sheet. This technique was further revised and developed with crosstalk reduction method recently in [15]. But the main issue with the cross-lenticular is that it generates moiré effect due to pattern matched with the pixel sheet. This paper presents a moiré-free full parallax 3D display based on crosstalk-lenticular technology.



(a) *(b)*

Fig 1. Block diagram of cross-lenticular sheet [15]

In this paper, we further study the moiré effect and identify its cause and then propose a slanting angle for removing the moiré effect in cross-lenticular approach.

2 THE PROPOSED SLANTED CROSS-LENTICULAR

The traditional structure of the cross-lenticular sheet is shown in Fig 2, which shows two lenticular sheets are packed together face-to-fact then only the bottom one's focal length (thickness) is used by both lenticular sheets. The overlapped section of the two lenticular sheets forms a square aperture microlens which corresponds to elemental images.

The cross-lenticular approach is investigated using white background image because in white background, the moiré effect is easily noticeable. It is identified that the horizontal lenticular sheet generates the moiré effect as its pattern matches with the LCD pixel sheet as shown in Fig 3 (a). Also, it is experimented through replaying of an omnidirectional holoscopic 3D image and the moiré effect is persistent as shown in Fig 3 (b).

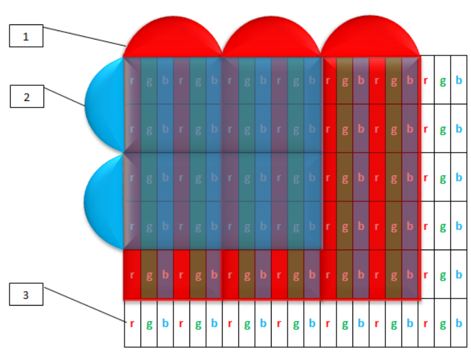
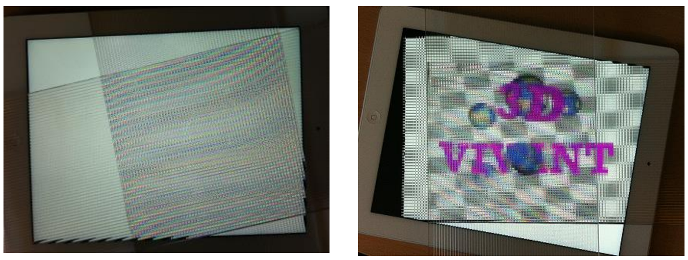


Fig 2. The traditional structure of cross-lenticular sheet: Label description: (1) Horizontal lenticular sheet, (2) vertical lenticular sheet, (3) liquid crystal display pixel sheet

(a) white background *(b) H3D image*

Fig 3. The analysis of moiré effect in cross-lenticular approach

Another experiment is carried out by slanting cross-lenticular sheet by 18.43° degrees, which removes the moiré effect in the horizontal lenticular sheet but the moiré gets introduced by the vertical lenticular sheet because the LCD pixel sheet's pattern starts matching with the vertical lenticular sheet and the moiré direction is changed too.



(a) slanted white background *(b) slanted H3D image*

Fig 4. The resulting image of rotated cross-lenticular sheet

From the experiment shown in Fig 4, it can be concluded that the vertical lenticular sheet, which does not have a moiré effect is kept unslanted, instead the horizontal lenticular sheet is slanted. Therefore the proposed method shows in Fig 5, in which we rotate the horizontal lenticular sheet by 6.34° degrees which removes the moiré effect. The resulting playback result is presented in Fig 6.

After carrying out many experiments, we propose to slant the horizontal lenticular sheet for removing moiré effect in cross-lenticular approach and elemental images of the holoscopic 3D image requires pre-processing to align them with the proposed method.

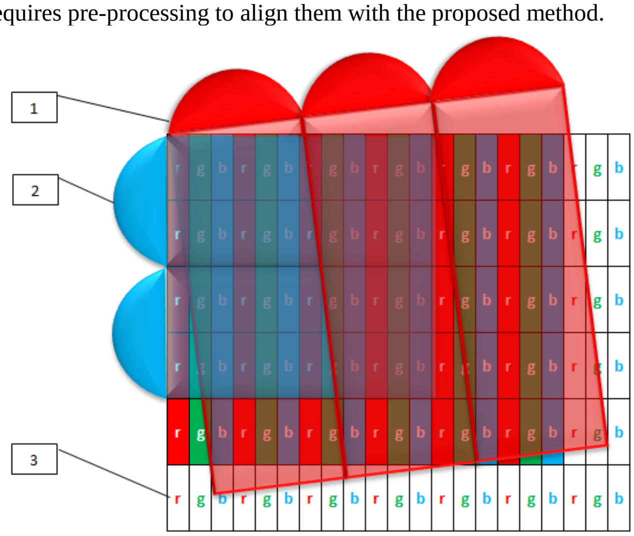
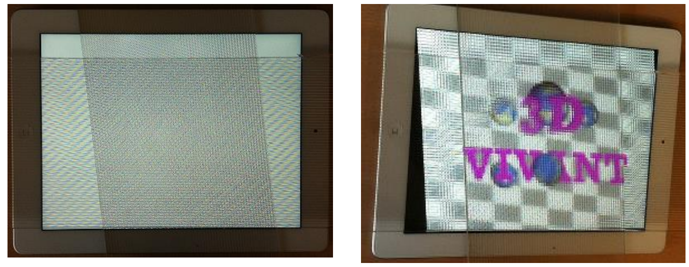


Fig 5. The proposed method - slanting the horizontal lenticular sheet: (1) slanted horizontal lenticular sheet, (2) vertical lenticular sheet, (3) liquid crystal display pixel sheet



(a) white background *(b) H3D image*

Fig 6. The experimental result of proposed method

3 HOLOSCOPIC 3D IMAGE RENDERING /PREPARATION

Holoscopic 3D computer graphics [4][5] is used in the experiments. We discussed in detail about the omnidirectional holoscopic 3D camera plugin [16], which has been developed in POV-Ray [17]. This is used to render holoscopic 3D images with the 3D display lens specifications. The elemental images are remapped according to the proposed slanting method shown in Fig 5. The process is to remap horizontal viewpoint pixels in correct manor to match the proposed slanting angle.

A pixel mapper tool is developed that remaps a traditional holoscopic 3D image into the proposed method by re-mapping the elemental images to match rotated angle of the lenticular lens before the holoscopic 3D image can be replayed on the 3D displays.

4 THE HOLOSCPOIC 3D DISPLAY

We have built a Cross-lenticular Full Parallax Holoscopic 3D display, which offers moiré free full parallax 3D image visualization. The 3D display is built using an iPad 3 with two pieces of lenticular sheets. The detailed information is presented that includes pixel pitch size, microlens pitch, and focal length shown in Table 1.

Table 1. The holoscopic 3D display specification

Items	Specification
Liquid Crystal display	*Retina iPad 3*
Pixel pitch	*0.0965(H) × 0.0965 (V) mm*
2D Resolution	*2048 × 1536 pixels*
Pixels per lens	*22 × 22 pixels*
Microlens pitch	*2.1165 mm*
Focal length	*2.0 mm*

5 CONCLUSION

In this paper, we presented a Moiré-free full parallax 3D display based on cross-lenticular technology. The traditional cross-lenticular based full parallax 3D display has a moiré effect. We studied and analyzed cause of the moiré effect which is produced by the horizontal lenticular sheet. We propose to slant the horizontal lenticular whereas the vertical lenticular sheet remains the same in cross-lenticular approach. The experiment results illustrated the proposed method removes the moiré effect in cross-lenticular based full parallax 3D Display.

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