Large FOV Head-mounted Display Based on Computer-generated Hologram

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Abstract:

The large FOV HMD based on CGH technology was proposed in this study. The proposed device was composed of two holographic lenses and a single SLM. The FOV of the proposed device is about four times the diffraction angle of SLM.

1. Introduction:

In recent years, rapid advances in technology have invented devices that need to make human life more convenient. These include head-up displays (HUD) and head-mounted displays (HMD), one of these types of displays in various functions is to type of application to allow the car and locomotive to efficiently obtain vehicle body information, while reducing the risk of distraction by the driver. However, traditional optical components are inconvenient to carry or install due to the weight and volume of the system. On the contrary, holographic optical elements (HOE) can be used to solve this problem. On the other hand, the computer-generated hologram (CGH) technique and spatial light modulator (SLM) are necessary if the dynamic display with depth information is desired [1]. However, the FOV of the image will be limited by the pixel size of the SLM. Therefore, the purpose of this study is employing two HOEs to reduce the pixel size of the SLM to enlarged the FOV of system, at the same time, this system has the ability to freely switching the input image [2, 3]. Finally, because of the use of HOE, this device and helmet can also be greatly increased the possibility of head-mounted device combination.

2. Experiment:

Fig. 1 is a schematic diagram of the system in the experiment. First, input the target image into computer and calculated by the algorithm for generate the CGH and transmit into the SLM, then the information light is transmitted through the SLM diffraction to HOE 1 at a distance of 20 cm from the SLM. And adjust the position of the final image through SLM. The final image in this experiment is located 50 cm behind the observer. The HOEs consist of a pair of asymmetric holographic lenses which were utilized to form the demagnified real image of SLM. The CGHs in this study were calculated via the iteration Fourier transform algorithm (IFTA). However, the HOEs will cause serious astigmatism. In the previous research, astigmatism can be compensated via a holographic cylinder lens. First, input the target image into computer and calculated by the algorithm for generate the CGH and transmit into the SLM, then the information light is transmitted through the SLM diffraction to HOE 1 at a distance of 20 cm from the SLM. And adjust the position of the final image through SLM. The final image in this experiment is located 50 cm behind the observer.

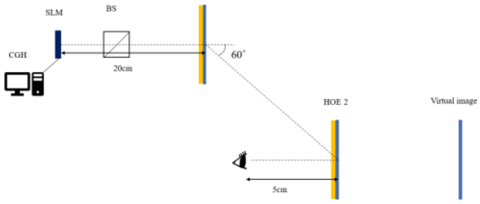
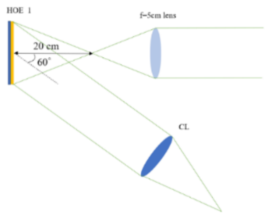
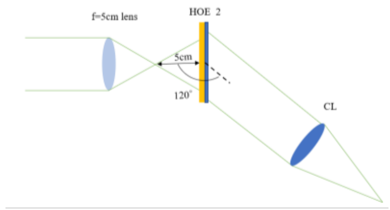


Fig. 1 The schematic diagram describes the configuration of the proposed device.

The shooting structure of HOE 1 in this experiment is shown in Fig. 2(a). First, starting from a laser light with a wavelength of 532 nm and dividing the light into two parallel rays of the same polarization, HOE 1 will use a 20 cm diffuse spherical wave and the parallel light incident obliquely interferes to form a penetrating holographic lens. The structure is shown in Fig. 2(a); HOE 2 uses a 5 cm diffuse spherical wave to interfere with parallel light incident obliquely at 120°, forming a reflective holographic lens, the structure is shown in Fig. 2(b).



(a)



(b)

Fig. 2 The schematic figure describes the interference configuration(a) HOE1;(b) HOE2.

Since it is necessary to confirm that the image is indeed reduced by 4 times to determine whether the FOV is enlarged, an experiment to confirm the image size is designed. After entering the pattern with a laser parallel light, the camera is used to simulate the human eye and a ruler is added to the paper screen to observe and confirm the image size, as shown in Fig. 3. And Fig. 4 shows the image observation architecture after adding the CGH system to the HOEs system.

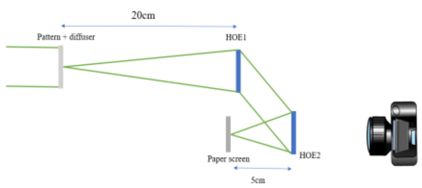


Fig. 3 The experimental configuration was utilized to verify the reduced pixel size.

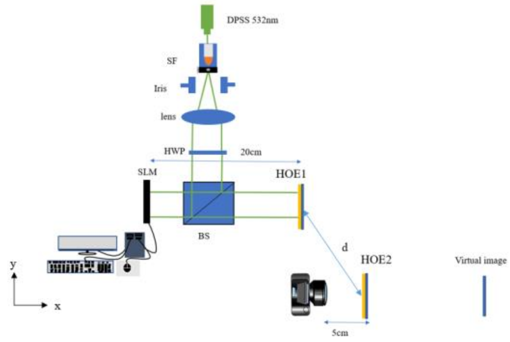
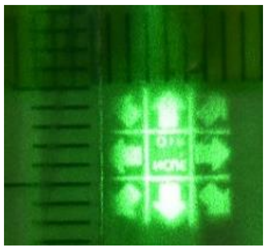


Fig. 4 HOEs system composed of the CGH system.

3. Results:

Fig. 5(a) is to confirm the pattern information placed in the image reduction structure. The pattern is a 3×3 square with a side length of 1 cm. Fig. 5(b) is the image after imaging and includes the ruler. It can be seen in the figure that the side length is reduced to 0.25 cm so that it is indeed reduced by 4 times.

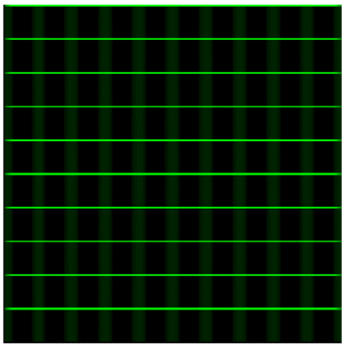
(a)



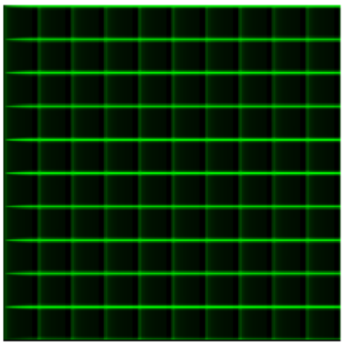
(b)

Fig. 5. (a) Input the 1 by 1 cm/grid image of the pattern (b)The image through the system in Fig. 3 and zoom out by 4 times.

Through Zemax simulation, it can be known that this system has serious astigmatism as shown in Fig. 6(a) and that is the image simulation diagram. Therefore, to correct the astigmatism you can inverse the simulation to get the position where the simulation imaging surface should exist, and then bring it back to the simulation. Them you can discover the astigmatism has been corrected, as shown in Fig. 6(b). Using the schematic diagram in Fig. 4 and let the Fig.7(a) to be the target image through the algorithm to generate CGH and input the CGH to the system by SLM. Then you can see a virtual image in Fig. 7(b), and it is lie in 50 cm in front of the camera, but because of the serious astigmatism the image cannot be identify with target image as shown in Fig. 7(a). Shifting tangential and sagittal plane can correct the astigmatism and the value of shifting can be obtain by Zemax simulation. In this case, distance between HOEs is 260 mm and the tangential shift is at 50 mm in front of the SLM and the sagittal plane is at 2692 mm behind the SLM. And the corrected virtual image is shown in Fig. 7(c).



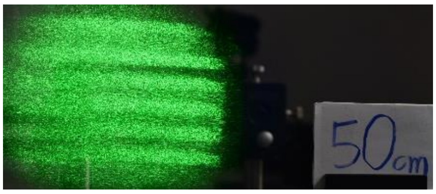
(a)



(b)

Fig. 6 The image simulation diagram (a) before correct the astigmatism (b) after correct the astigmatism.

(a)



(b)

(c)

Fig. 7 (a) the target image to put into the algorithm and generate CGH and virtual image is 50 cm in front of the camera (b) the astigmatism is not corrected and (c) the astigmatism is corrected.

In Fig.7 (c) that the astigmatism is been successfully corrected, but image quality can be better, and it is due to tangential shift is smaller than 250 mm it will cause the SLM pixel sampling rate too low, but through changing the distance between HOEs it can get a new tangential and sagittal shift. After searching, a suitable set of data has been decided that is the new distance between HOEs is 100 mm and the new tangential plane is at 259 mm in front of the SLM and sagittal plane is at 275 mm behind the SLM.

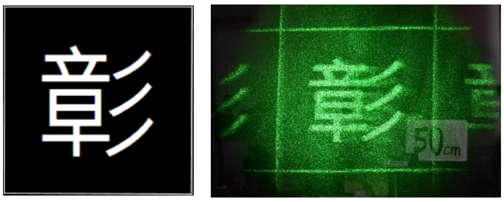
In terms of FOV, using the target image to generate CGH as shown in Fig. 8(a). After the image through the CGH and HOEs system in Fig. 4 and corrected the astigmatism there will be a virtual image at 50 cm in front of the camera, as shown in Fig. 8(b), then placed a paper screen and measured the horizontal distance to the borders on both sides is 18.8 cm and the vertical distance is 17.4 cm, using formula (1) to calculated the horizontal FOV is 21.29° and the vertical FOV is 19.74°.

On the other side, because of the pixel size of SLM is 6.4μm, and using formula (2) to calculated the horizontal and vertical FOV would be 4.764°, however after the system reduces the pixel size of SLM by 4 times, the FOV can also be calculated by formula (2) to obtain a horizontal and vertical FOV of 19.14°.

$$\theta = 2 \times \tan^{-1} \frac{\text{half height of image}}{\text{distance between paper screen}} \cdots (1)$$

$$\theta = 2 \times \sin^{-1} \frac{\lambda}{2p} \cdots (2)$$

Among them, θ in formula (1) is the FOV, λ is the wavelength, and p is the pixel size of the SLM.



(a) (b)

Figure 8. (a) target image which put into the system (b) virtual image that is 50 cm in front of camera.

4. Discussion:

Using Zemax simulation, a serious problem of astigmatism has been found, then according to the previous research astigmatism can be corrected by shifting tangential and sagittal plane [4]. This has also been verified experimentally, but the problem of eliminating astigmatism and background noise still exists, so the follow-up work is still Need to work hard in this part. Because of the current HOE used green light with a wavelength of 532 nm to shoot, so only green images can be presented. In the future, full-color images can be presented in a wavelength-multiplexed manner. Finally, it can be packaged with a safety helmet of a suitable size to achieve the purpose of being designed as a head-mounted display.

5. Conclusion:

This topic verifies the reduction ratio of the image after the HOEs system and tests the FOV of the holographic optical system combined with SLM. These HOEs have the same effect as a lens, and can achieve the purpose of reducing the size of optical components, which is quite excellent; Astigmatism can be compensated by Zemax simulation and adjustment of the SLM imaging position. In addition, this system reduces the pixel size of the SLM to further provide a larger FOV, and with reduction of experiment error, the horizontal and vertical FOV can also approach 19.14°.

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