Realistic AR 3D displays without AC conflict

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ABSTRACT

Virtual reality (VR) and augmented reality (AR) technologies are gaining ever-increasing attention. However, there is vergence-accommodation conflict problem for most VR or AR 3D displays, causing visual fatigue. We propose solutions to realize realistic AR 3D displays without AC conflict based on liquid crystal devices and metasurfaces.

1 Introduction

Metaverse is likely to revolutionize people’s lives in many ways. As the entry to metaverse, virtual reality (VR) and augmented reality (AR) technologies are gaining ever-increasing attention. Though many AR products have been released and prototypes demonstrated, most near-eye 3D displays for AR applications are based on simple stereoscopic technique. Such displays could not realistically present virtual 3D image and fail to provide all the physical depth cues correctly, resulting in vergence-accommodation conflict (VAC) and causing visual fatigue and discomfort [1, 2].

To solve the VAC problem, we adopted several approaches to realize more realistic 3D display [3-8] based on liquid crystal (LC) devices and metasurfaces. One approach is to realize vari-focal/multi-focal display based on LC scattering films or variable LC lens. Another approach is to realize an always-in-focus Maxwellian viewing display based on a novel multi-functional metasurface lens.

2 Multi-focal AR display based on tunable LC scattering films

To realize vari-focal or multi-focal display, it is crucial to have electro-optical devices that can switch between different status. If the image source is made of switchable LC films placed at different spatial locations, and each LC film can be switched between transparent and scattering states, the 2D cross sections of a 3D volume could be rendered by switching the LC films [4-5]. With an eye piece and a combiner, virtual images could be generated at different depths at different moment in front of eye, forming realistic 3D virtual image augmented on the real world. If the switching is fast enough, multiple depth could be rendered simultaneously thanks to the persistence of human eye. We have developed fast-response LC scattering films with sub millisecond response time and good optical properties, and experimentally demonstrated multiple-plane AR virtual images.

Fig. 1 Multi-focal AR display

3 Vari-focal AR display based on tunable LC lens

Alternatively, with a 2D microdisplay and a variable lens, image depths could also be varied. As eye tracking detects the vergence distance, one could change the focal length of the eyepiece lens and vary the depth of the image the 2D microdisplay to match the vergence distance. We have developed tunable lens based on liquid crystal devices including Alvarez lens, and stacked lenses [7]. We could fabricate LC devices with arbitrary phase profile and planar form factor with low voltage and power consumption. We also implemented AR display prototypes with these tunable LC lenses, and rendered images at different depths. By employing the multi-focal or vari-focal display technique in AR display, we could invoke the correct accommodation depth cue to match the vergence depth cue, and thus eliminate VAC and 3D visual fatigue.
4 Maxwellian Viewing AR display based on metasurface lens and LCoS

The previous mentioned method tends to provide the correct accommodation, while another way to overcome VAC problem is to use the Maxwellian viewing display with provides no accommodation depth cue at all. Since in a Maxwellian viewing display, light of image forms a tiny point at pupil position, no matter how the eye adjusts its focus, clear image could always be formed on the retina, therefore, there is no depth information could be inferred from eye accommodation adjustment. With no accommodation depth, human brain would just follow what the vergence suggests, and thus, VAC problem could be solved. We have proposed a Maxwellian viewing display based on a novel multi-functional metasurface lens.

Metasurfaces are attractive for AR display applications because of their thin form factor, large deflection angle and high degree of design freedom. Different from conventional transmissive or reflective metasurface lenses, our multi-functional metasurface lens can reflect and focus off-axis light, and transmit normal incidence. Hence, it could function as a beam splitter and an eyepiece in one.

With such a multi-functional metasurface lens and a LCoS (liquid crystal on silicon) image source, we demonstrated the always-in-focus Maxwellian viewing display with red, green and blur virtual images.

5 Conclusions

To overcome the VAC problem and alleviate 3D visual fatigue, we have solutions to realize realistic AR 3D displays without AC conflict. Multi-/vari focal AR display is realized based on LC scattering films and tunable LC lenses. Maxwellian Viewing display based on multi-functional metasurface lens can generate always-in-focus virtual images.

References