Design of Optical System of Augmented Reality Near Eye Device

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***Abstract*—Augmented reality (AR) is a technology that instantly merges digital pictures with the real scene. The perspective near-eye display is a key module of AR, through which computer-generated pictures or videos can be displayed in the existing environment. The purpose of this research is to establish the system structure of an augmented reality near-eye display device and to design the off-axis two-piece reflective aspherical mirror. Because AR glasses are wearable and are worn close to the eyes, not only the optical performance of the display but also the clear vision of the user needs to be considered. In this study, an off-axis two-piece reflective aspherical mirror is used as the optical system of the AR for displaying the digital image. The micro-display is placed at the focal point of the optical system to form a digital image, and the horizontal movement of the micro-display along the optical axis is controlled by a precise displacement mechanism so that the patient with uncorrected myopia or hyperopia can see the digital picture and real scene. Because the right and left micro-displays move horizontally independently, the user can see the images on the AR device, which becomes the biggest feature of this study.**

Keywords*—*Augmented reality, parabolic, focal length

I. INTRODUCTION

Augmented reality (AR) technology is an optoelectronic technology that combines computer-generated virtual objects with the real-time world. Based on computer science, it performs simulation processing, superimposes real information content, and effectively applies in the real-time world. In this process, scenes can be perceived by human eyes as an experience beyond the immediate senses. After the real environment and the virtual object overlap, it can exist on the same screen at the same time [1,2]. AR is closely related to hardware, software, and application. In terms of hardware, the combination of an image processor, display, sensor, and input device is suitable for the AR platform. In terms of software, the key to the AR system is how to combine augmented objects with the real world. After a special optical mechanical design, the human eye can see static and dynamic digital images and a real-time scene superimposed image. Usually, the dizziness caused by wearing an augmented reality device is related to the fusion mechanism of the human body, so many parameters need to be resolved, including visual time delay, visual convergence conflict (VAC phenomenon), and highly concentrated thoughts. In this study, the optical design method is for the micro-display at the focal point of the aspheric mirror system to make small movements, allowing the user to quickly generate fused images to reduce dizziness.

II. PRINCIPLE OF FOCAL COLLIMATOR

The focal collimator is widely used in the field of optical testing. In this study, using the optical properties of the focal collimator as an augmented reality device, fine-tuning the focus on the micro-display, providing it to myopia users with different diopters, Thus, the left and right eyes can produce clear digital images and achieve the purpose of fusion. The focus collimator consists of an objective lens and a reticle at its focal point, and the focal length of the objective lens and the size of the reticle must be accurately known. Setting up the test lens and using a measuring microscope, the size of the reticle image is measured accurately after the test lens is imaged [3−5]. Figure 1 shows that the focal length of the test lens is given by

$$F_2 = A_2 \times (F_1/A_1) \quad (1)$$

where A_2 is the image size of the reticle after being imaged, A_1 is the size of the standard reticle, and F1 is the focal length of the collimator. When one of A_2, A_1, and F_2 is inaccurate, this causes a measurement error of focal length F_2. If the lens to be tested has large distortion, a small angle measurement must be used but the practicality of the large viewing angle is limited.

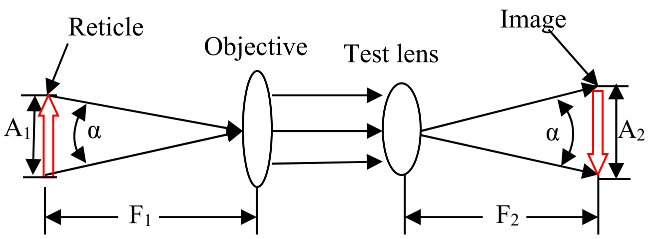


Fig. 1. Illustrating the focal collimator methods of measuring focal length on the optical bench.

When setting up the collimator, the constant of the collimating lens (F_1/A_1) must be determined as accurately as possible. The width of the cross-line and the size of A_1 of the reticle can be easily measured with a measuring microscope. The focal length F_1 of the collimator can be measured with a focal meter. The collimated beam is parallel to the optical axis of the positive lens and is focused on the focal point after it enters the positive lens. The distance between the lens and the focal point is called the focal length (f). Conversely, a point light source placed at the focal point of the lens is converted into a collimated beam. If the distances between the object and the lens and between the lens and the image are S_1 and S_2, the distance is related to the thin lens equation for a lens with negligible thickness in the air.

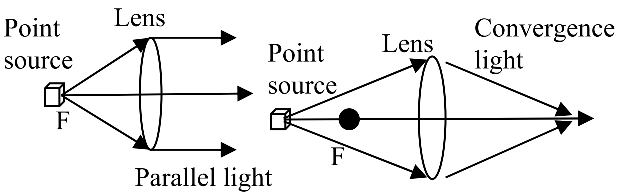
$$(1/s_1)+(1/s_2)=1/f \quad (2)$$

This can also be put into the "Newtonian" form as

$$X \text{ x } x'=f^2 \quad (3)$$

where $x=s_1-f$ and $x'=s_2-f$.

The refractive power of a lens in diopters is numerically equal to 1 m divided by the focal length in meters. The algebraic sign of the magnifying power indicates whether the lens causes an incident parallel light to converge or to diverge. Figure 2 shows the change of the image distance when the object distance changes and F is the focal point of the lens.



(a) Point source at F (b) Point source keep away F

Fig. 2. Parallel Light and the Convergence Light of Lens.

III. System and Experiment Results

The general binoculars are composed of two refracting telescopes installed side by side and pointing in the same direction. The viewer uses both eyes to view distant objects at the same time. The system structure is similar to binoculars, and the eyepiece of the adjustable diopter is symmetrical on the left and right, including optical axes of the left and right, the left and right perspective windows, and the internal space. The left and right optical axes are parallel to each other and are connected to their respective perspective windows, and each corresponds to the user's eyes. Through the left and right perspective windows, both eyes look directly along the optical axis of the AR near device system to see the composite image of the real scene outside and the digital picture. The internal space is mainly composed of a microdisplay with digital image generation, a reflective aspherical mirror system for imaging, a diopter adjustment device for the eye of refractive error, two mirrors set similar to the corner cube for making the light ray reflect 180° and an optical beam-splitter for combining digital image and real-time (Fig. 3). The two-mirror set is composed of beam splitters and plane mirrors inclined at 45° respectively along the vertical direction, one above and one below. The mirror face is opposite each other, facing the direction of human eyes. The micro-display is used to generate the digital scene that is placed on the focal plane of the aspheric mirror system i, imaged at infinity and superimposed with the external real-time scene through the two-mirror set. The diopter adjustment device is connected to the micro-display to drive the micro-display at the focus of the aspheric system and move left or right along the optical axis with the focus as a reference point so that the user can see a clear digital image and a real-time scene superimposed image. Table I shows the calculation of the horizontal distance (x) required to move the object in focus along the optical axis under different myopia refractive powers (S) of the human eye. The equation for calculating the refractive power of myopia S is proportional to one divided by the x'(m) and the S unit is diopter (D).

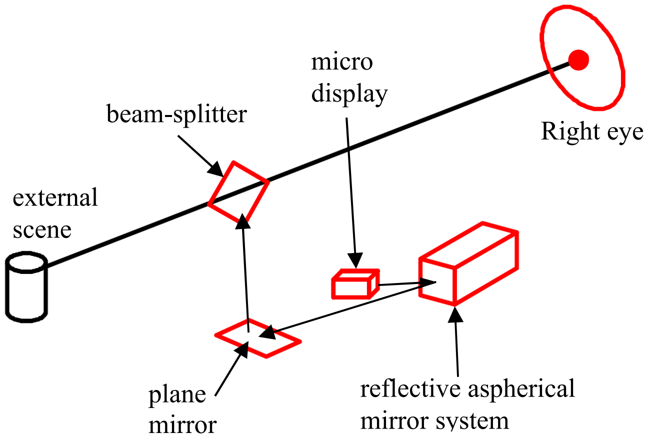


Fig. 3. One side of Optical System.

TABLE. I. CALCULATION OF THE X WITH VARIOUS S OF THE HUMAN EYE.

X (mm)	x' (m)	S (D)
0.5	0.80	1.25
1.0	0.40	2.50
1.5	0.266	3.75
2.0	0.20	5.0
2.5	0.16	6.25
3.0	0.133	7.50
3.5	0.114	8.75
4.0	0.100	10.0
4.5	0.089	11.36

IV. Conclusion

This research is about an augmented reality near-eye device. According to newton's thin lens equation, the micro-display located at the focal point of the optical system is fine-tuned to the left or right along the optical axis with the focal point as the origin so that both eyes can see the composite image of the real scene outside and the digital picture. The relationship between the micro-display fine-tuned distance and the human eye diopter is listed in Table I. The reflective aspherical mirror of the research is used in a wide spectrum range. The optical path of the optical system is folded, which reduces the volume and weight. The optical system of this study can also be used for hyperopia and presbyopia.

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