A Stereoscopic Display with Large Field of View Using Maxwellian Optics

Masahiko INAMI, Naoki KAWAKAMI, Taro MAEDA,
Yasuyuki YANAGIDA, Susumu TACHI

Faculty of Engineering, University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo, 113 JAPAN

minami@star.t.u-tokyo.ac.jp, kawakami@star.t.u-tokyo.ac.jp,
yanagida@star.t.u-tokyo.ac.jp, maeda@star.t.u-tokyo.ac.jp, tachi@star.t.u-tokyo.ac.jp

Abstract

Conventional stereoscopic displays have inconsistent accommodation against convergence, which degrades sensation of presence. We developed a stereoscopic display applying Maxwellian optics to avoid such inconsistency by realizing large depth of focus. The display was also designed to provide large field of view (about 110 degree) with the simple optics. And this display allows an operator to observe real and virtual images in focus for wide range of depth.

Key words: Maxwellian optics , convergence accommodation , stereoscopic display , augmented reality , virtual reality

1. Introduction

In the field such as virtual reality, the head mounted display (HMD) is used very well.[1][2]

HMD can display surrounded image without large-scale device like OMNIMAX and CAVE[3]. But it has many problem. For example, small filed of view, eye fatigue by accommodation inconsistency against convergence. Furthermore, see-through display which is useful for Augmented Reality have inconsistent depth of CG image with the depth of real world.

So, we expend the problem of conventional stereoscopic display first. Then we describe about new type display applying Maxwellian optics to avoid such inconsistency by realizing large depth of focus.

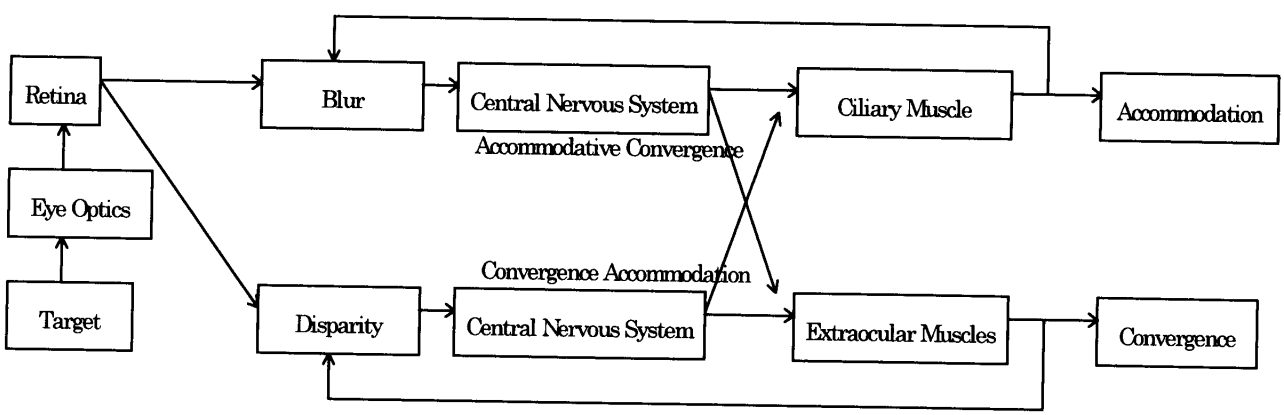


Fig.1. Diagram of Accommodation and Convergence

2. The problem of conventional HMD

2-1 Inconsistent accommodation against convergence

Binocular disparity and convergence are very important key for stereopsis. Then many stereoscopic displays include HMD are using binocular stereogram.

It is necessary an ideal stereoscopic display that various conditions (Ex. convergence, accommodation and object size on the retina) correspond between real image and virtual image. But conventional HMD's focus point is fixed on the distance of 1m or 2m. Then these HMD have inconsistent accommodation against convergence.

Accommodation and convergence affect each other. And the effect is observed as accommodative convergence and convergence accommodation.[4]

So we can change convergence comparatively with accommodation fixed. But inconsistent accommodation against convergence makes mistake to measure the distance. Especially this problem is more serious with See-through HMD. Because the observer can't focus both real image and CG image.

Then the valuable focus display was proposed to solve the problem.[5] But the method has other problems. For example, the display needs complex optics , eye-trucker and depth images. So this type display is not good for Tele-existence system.

2-2 Small field of view

Most conventional HMD have small field of view (30-60 degree), which degrades sensation of reality because peripheral vision is vary important for space cognitive. Several HMD have large field of view. But there need contact lends or very complex optics.

On the other hand, there is the display which has large filed of view and consistence between accommodation and convergence by scanning modulated light directly onto the retina of the eye.[6]

But this display needs LASER source and complex moving mechanism. And the display have trade-off between frame-ratio and resolution.

Then to use this display commercially, this display needs health assessment and more technical idea.

2-3 Inconsistent depth of CG image with the depth of real world

See-through display is very useful for Augmented Reality. And most conventional displays can separate following two types.

- Optical composition using half-mirror
- Electric composition using video-see-through

To compose of real image and CG image, optical method using half-mirror is very useful and this method display real world with large field of view, which is very important key for spatial localization.

But this method has a serious problem. Ordinary Augmented Reality system display stereoscopic CG image with static focus point. Then observer can't focus both virtual image and real object because of deference of focus pint.(Fig. 2.) To using this method makes observe virtual image and real object impossible at same time.

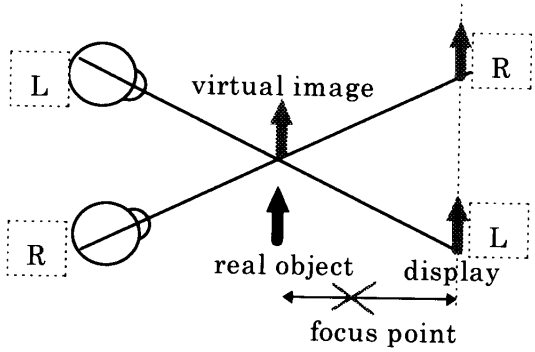


Fig.2. Inconsistent depth of virtual image against real image

On the other hand, video-see-through composition can equalize focus point between real object image and CG image. But this method has same problem as conventional HMD.

3 Principle of a display using Maxwellian optics

In bright environment, we can clearly observe sight because small pupil makes be large depth of focus to the eye.

The diameter of pupil is usually 2-8mm. If pupil become smaller using artificial pin-hole pupil, the eye can focus with any accommodation.

Pin-hole is an ideal lends. But to contact pin-hole with eye is too inconvenience. Then we propose to display through real image of pin-hole by Maxwellian optics.

This display has the following characteristics.

- More natural stereoscopy because of large depth of focus
- No compensation for ametropia
- It is possible to use the display of the various size (But it needs the bright display)

But this display needs bright image source because of pin-hole optics.

4 Development of the display using Maxwellian optics

4-1 System configuration

We already described the characteristics of the display using Maxwellian optics. But usual Maxwellian optics which use lends is poor for large filed of view. Then we developed them using a full concave mirror and a half mirror.

There are many kind of Maxwellian optics using a full concave mirror and a half mirror. Then we made experimental optics.(Fig.4)

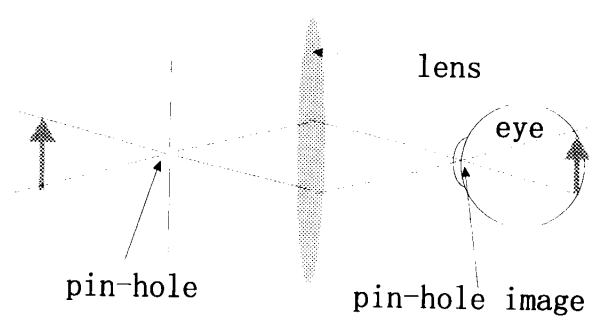


Fig.3. Maxwellian Optics

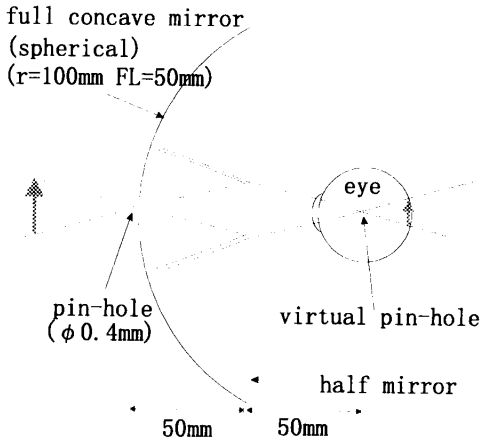


Fig.4. Maxwellian Optics Using Full Concave Mirror

And we made also see through display using Maxwellian optics. To use this display we can observe both CG image and real image at the same time.(Fig.5.)

This optics compose of real image and CG image using half-mirror. This method looks like similar related see-through display using half-mirror. But in this optics CG image is displayed through Maxwellian optics. Then observer can observe CG image even if he/she observes any distant real object.

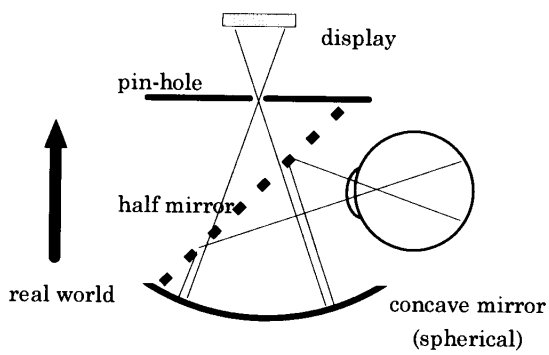


Fig.5. See-through Display Using Maxwellian Optics

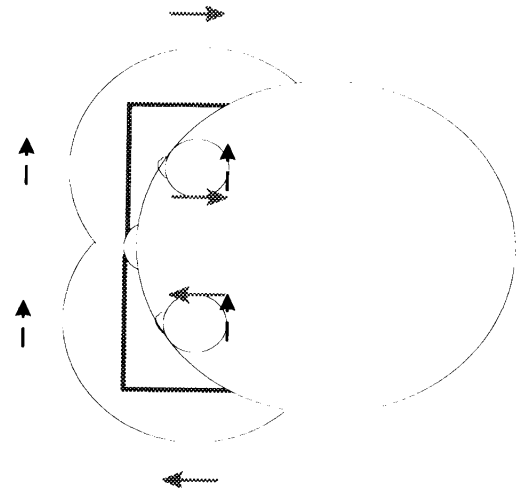


Fig.6. Concept of Large Field of View HMD Using Maxwellian Optics

4-2 Result

To use these optics we can observe large field of view (110 degree) and large depth of focus (20cm-infinity).(Table 1., Fig. 8)

In this data "static perimetry" means the field of view looking at target which is center of the full-concave mirror. And "kinetic perimetry" means the field of view when the observer is able to move his eye.

But this display has following fault.

- The field of view of this optics is effected by the diameter of the pupil
- Setting position against the eye is very tight

Then we used 0.5% tropicamide which makes the pupil large.

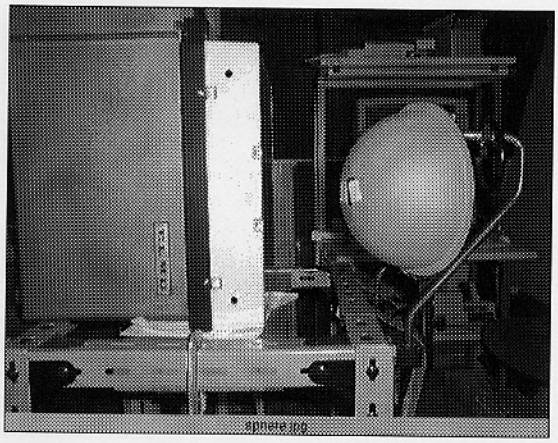


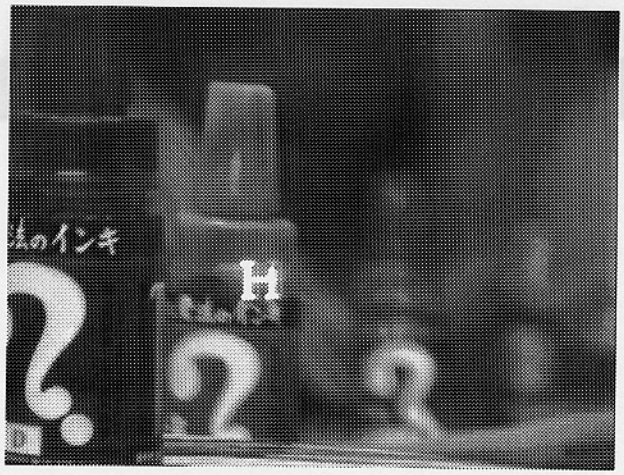
Fig.7. Photograph of the Experimental Hardware

Table 1. Field of view against pin-hole image position and pupil size

pin-hole image position	static perime-try (normal pupil)	kinetic perimetry (normal pupil)	static perimetry (loosen pupil)	kinetic perime-try (loosen pupil)
center of pupil	90°	–	110°	–
center of eye ball	40°	110° W 100° H	90°	110° W 100° H

5 Conclusions

In this paper, we described new type display using Maxwellian optics. To use this display we can observe large field of view and large depth of focus.



(a) focus point = 25cm

(b) focus point = 200cm

Fig.8. Experimental Result (See-through display using Maxwellian optics)

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