Visual Comfort Range in the Super-Multi-View Display

Dong-Wook Kim
Imaging Media Research Center
Korea Institute of Science and Technology
Seoul, Korea
Department of Physics
Korea University
Seoul, Korea
e-mail: 21@kist.re.kr

Sung-Kyu Kim
Imaging Media Research Center
Korea Institute of Science and Technology
Seoul, Korea
e-mail: kkk@kist.re.kr

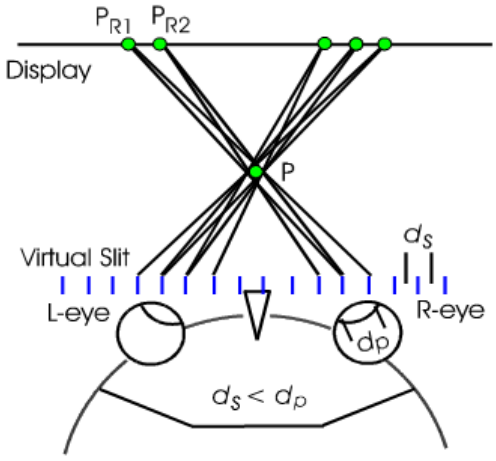
***Abstract*— We show a simulation result about visual comfort range in the super-multi-view display, using the depth of field condition related to the observer's pupil size. Through the simulation result, we confirmed that super-multi-view display can eliminate visual fatigue in wider depth range than the stereoscopic display. However additional elimination of visual fatigue due to super-multi-view effect is not possible.**

Keywords ; super-multi-view display, visual fatigue, the depth of field, disparity

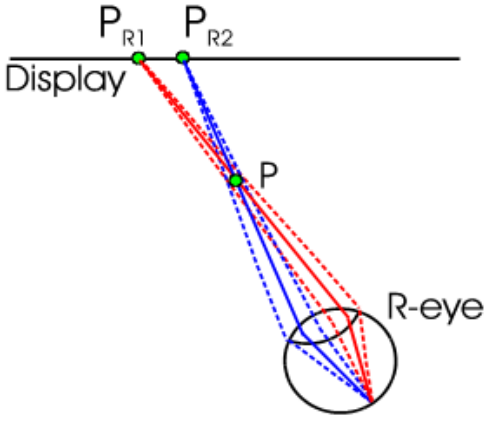
I. INTRODUCTION

The super-multi-view(SMV) display has an advantage to provide not only depth perception based on the binocular disparity, but also motion parallax. Therefore, it is recognized as one of the most next-generation display techniques [1,2]. SMV display provides natural motion parallax to a viewer by using more than two parallax images in one eye like as Fig. 1. As another advantage of this system, it is possible that visual fatigue due to conflict between monocular accommodation and binocular convergence in the stereoscopic display can be eliminated because of a possibility of accommodation effect like as Fig. 1(b). However, it is known that these SMV displays cannot provide perfect accommodation to the viewer [3]. Therefore, visual fatigue cannot be eliminated in the whole depth range.

Generally, it has been known that if expressed 3D depth range in the stereoscopic display is limited within the depth of filed (DOF) in order to solve the visual fatigue phenomenon, visual fatigue can be eliminated because defocus of image does not appear [4]. This DOF is related to viewer's pupil size regardless of viewing distance. In this case, although there are some difference according to each experimental method and human condition, DOF range is between 0.1D and 0.5D in the general pupil size (3~5mm) [5,6,7]. Therefore, DOF range is not wide. However, in case this result is applied to SMV display, wider DOF range is obtained because occupied area of viewing zone for one viewpoint in viewer's pupil is smaller due to providing more than two parallax images in one eye. Therefore, in this paper, we confirmed DOF range with visual comfort according to SMV condition and showed binocular and monocular parallax values according to this DOF range. In addition, we confirmed a possibility of additional elimination of visual fatigue due to principle of SMV display.



(a)



(b)

Fig. 1. Concept of SMV display. (a) Principle of SMV display. (b) Principle of monocular accommodation effect.

II. SIMULATION RESULT

Using simple lens equation, DOF is expressed as,

$$\frac{1}{\Delta O} = \frac{1}{f_O} - \frac{1}{\Delta i} \quad (1)$$

Where f_O is eye focal length and Δi is the depth of focus corresponding DOF.

The depth of field related with pupil size is expressed as,

$$\Delta i = \left[-22.8 \times \left(\frac{D}{b - D} \right) \right] - \left[22.8 \times \left(\frac{D}{b + D} \right) \right] \quad (2)$$

Where, D is pupil size, b is confusion circle size, and *22.8mm* is eyeball diameter.

Figure 2 shows calculated DOF result from SMV condition at 1m viewing distance. Dot line of Fig. 2 means display position. In the calculation, D was *5mm* and b was 13 μm . b value is decided, as considering lens aberration and visual accuracy of eye [8].

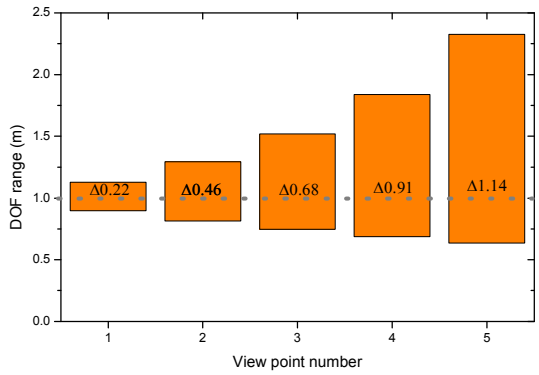


Fig. 2. DOF of 1m viewing distance according to the number of viewpoint of one eye.

In Fig. 2, one viewpoint means a general stereoscopic condition. When it is compared with SMV condition using more than two viewpoints, SMV display has wider DOF range than the stereoscopic display. Also if the number of viewpoints provided to one eye is more, the DOF range is wider. At this time, in SMV condition, diffraction-limited can be ignored because viewpoint width (1~2.5mm) is smaller than pupil's (5mm). Therefore, SMV display can widen DOF range without diffraction problem. Consequently, in relation to providing the number of viewpoints, SMV display has wider DOF range without visual fatigue, when compared with the stereoscopic display. Also, DOF value of our simulation is similar to results of subject experiments. So, we can know that our simulation result is correct.

Figure 3 shows permissible binocular and monocular disparity according to the number of monocular viewpoints of DOF range in Fig. 2. Expressed value means front and rear disparity based on the screen as absolute value. In Fig. 3, as provided viewpoint increases, a permissible binocular disparity is increased, but monocular disparity is uniform. However, depth position expressed by same monocular disparity is different according to the number of viewpoints. Therefore, if parallax images are provided to the viewer within this binocular and monocular disparity values, the viewer can see 3D image without visual fatigue.

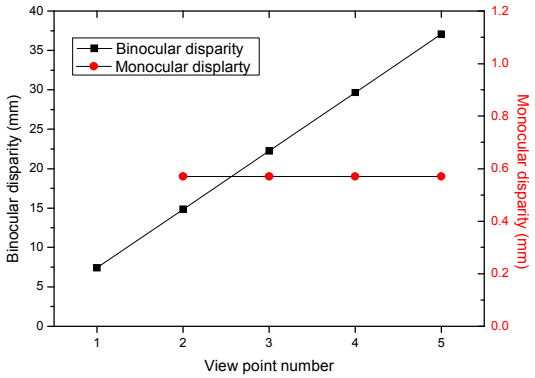


Fig. 3. Permissible binocular and monocular disparity according to monocular viewpoint in DOF range.

As above mentioned, defocus does not appear within DOF range so that accommodation effect due to principle of SMV display (Fig. 1(b)) is possible. Therefore, in order to confirm possibility of additional elimination of visual fatigue due to principle of SMV display, we confirmed whether accommodation response about 3D object on the outside of DOF range is possible without defocus.

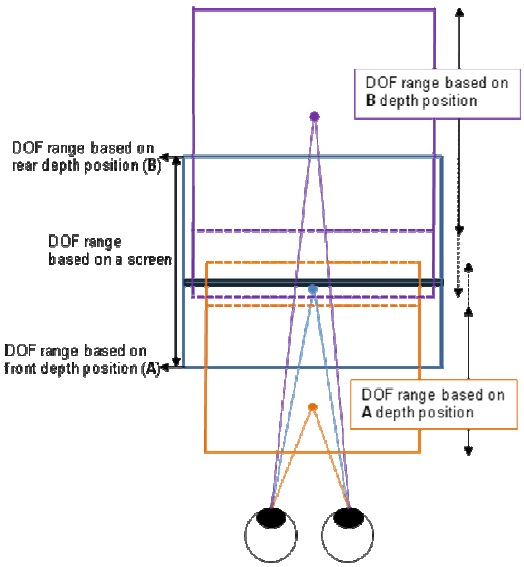


Fig. 4. DOF ranges according to viewer's each gazing depth.

Viewpoint in the monocular (ea)	*Front (A) DOF position at display*	*Rear (B) DOF position at display*	*DOF range at (A) depth*		*DOF range at (B) depth*	
2	0.814m	1.295m	0.687m **1m**	Δ0.46D	**1m** 1.839m	Δ0.46D
3	0.745m	1.520m	0.594m **1m**	Δ0.68D	**1m** 3.167m	Δ0.68D
4	0.687m	1.839m	0.53m **1m**	Δ0.91D	**1m** 11.4m	Δ0.91D
5	0.637m	2.327m	0.467m **1m**	Δ1.14D	**1m** infinity	Δ0.99D

Table 1. DOF range at each front (*A*) and rear (*B*) position based on screen in above simulation condition.

Figure 4 shows DOF ranges according to viewer's each gazing depth. If viewer gazes on the outside of front or rear depth position (*A* or *B* position of Fig. 4), the viewer has another DOF range based on new gazing point. If this DOF range includes screen position, accommodation response due to principle of SMV display will be possible. Table 1 shows DOF range at each front (*A*) and rear (*B*) position based on screen in above simulation condition. In the result of Table 1 using Eq. (1) and (2), regardless of the number of viewpoints, in case the viewer gazes on the *A* or *B* position of DOF range, a boundary position of another DOF is screen position (1m). Therefore, if viewer gazes on the outside of *A* or *B* position, viewer cannot obtain perfect accommodation effect due to a defocus of image source. In other words, additional elimination of visual fatigue due to principle of SMV display is impossible. For reference, Fig. 5 and 6 show variation of front and rear position of DOF according to viewer's gazing depth. Dot line means a display position. However, SMV display can provide 3D effect to the viewer due to accommodation using monocular parallax images within DOF range based on the screen.

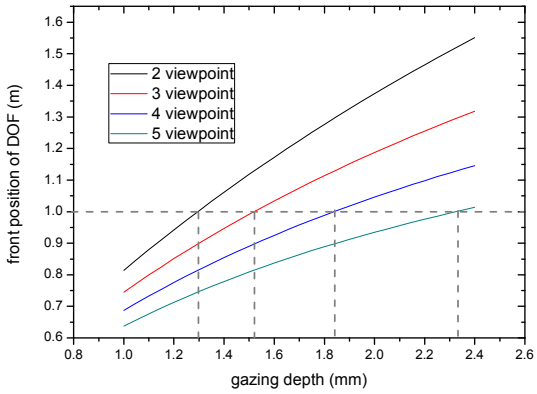


Fig. 5. Variation of front position of DOF range according to viewer's gazing depth.

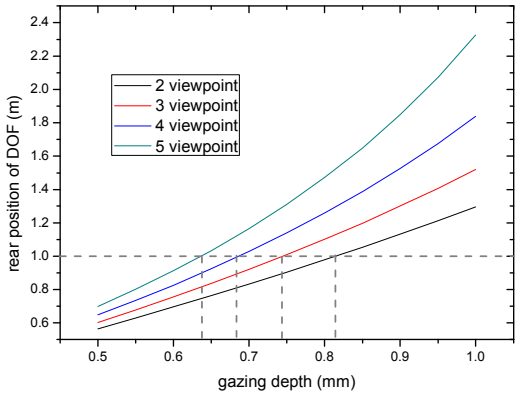


Fig. 6. Variation of rear position of DOF range according to viewer's gazing depth.

III. CONCLUSION

We showed the simulation result about visual comfort range in SMV display, using DOF condition related to the observer's pupil size. Also, the condition of binocular and monocular disparity corresponding with DOF conditions is calculated. Therefore, if parallax images according to calculated disparity are provided to the viewer, viewer can see 3D image without visual fatigue. In addition, regardless DOF condition, we confirmed that expanding range of accommodation response due to principle of SMV display is impossible. However, within DOF range, SMV display has an advantage that principle of SMV display can provide 3D effect by accommodation.

IV. REFERENCE

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