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Study on Distortion and Field of View of Contents in VR HMD

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Abstract

Recently, VR HMD (virtual reality head mounted display) has been utilized for virtual training, entertainment, vision therapy, and optometry. In particular, virtual reality contents are increasingly used for vision therapy and optometry. Accordingly, high-quality virtual reality contents such as a natural vision of life is required. Therefore, it is necessary to study the content production according to the optical characteristics of the VR HMD. The purpose of this paper is to suggest a proper FOV (field of view) of contents according to the distortion rate. We produced virtual reality contents and obtained distorted images by virtual camera. The distortion rate is calculated by using the distorted image. It is proved that the optimal FOV of the VR content with the minimum distortion is 90 ~ 100 °. The results of this study are expected to be applied to the production of high quality contents.

Keywords: *Virtual Reality, Head Mounted Display, Field of view, Distortion*

1. Introduction

As demand and supply of VR HMD increases, the application of virtual reality contents in different fields are also increasing [1-2]. The main application areas are military, education and other entertainment industry such as games and movies, tourism [3-4]. Virtual reality content can also be used in the vision therapy field. Recently, studies have been carried out as training equipment such as visual function test and amblyopia treatment using VR HMD [5-6].

The user sees the virtual reality content information executed in the VR HMD through the human eye and the convex lens. At this time, when a collision of visual information with the vestibular system occurs, a motion sickness is induced [7]. The factors that cause the motion sickness are the personal factors and the technical factors [8]. The FOV is a technical factor, and motion sickness occurs because the user accepts FOV information different from usual [9]. Therefore, the FOV in virtual reality contents is an important factor for motion sickness.

This paper aims to study the content distortion and FOV based on VR HMD. To do this, we produce virtual

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reality contents with concentric circles. And we use various virtual camera FOV to obtain distorted images. Finally, we calculate the distortion rate based on the acquired image and suggest a proper FOV.

The composition of this paper is as follows. In Chapter 2, we describe the human visual field and the VR content FOV. In Chapter 3, virtual reality contents are acquired by using virtual cameras with various FOV. Through the images obtained from the experiment, we calculate the distortion rate and propose the appropriate FOV. Finally, Chapter 4 concludes the study of distortion and FOV in VR HMD content.

2. Field of view

2.1 Visual field

The visual field is a range of spaces that a person can perceive at a time through the eyes. The visual field is divided into a monocular visual field and a binocular visual field. Monocular visual field is the range of visual information that can be obtained through monocular vision. The monocular visual field is 60 ° in the superior limit, 75 ° in the inferior limit, 60 ° in the nasal limit, and 100 ° in the temporal limit visual field at the center of the visual line [10]. Binocular is a visual field in which the left and right visual fields are overlapped. The left and right eyes have different ranges of visual field. Due to the difference in visual field of the left and right eyes, the two monocular visual fields are not completely overlapped. Table 1 shows the parameters of monocular visual field and binocular visual field.

Table 1. Human visual field parameters

Parameter	*Value*
Superior limit	60 °
Inferior limit	75 °
Monocular nasal limit	60 °
Monocular temporal limit	100 °
Binocular visual field	120 °

2.2 VR HMD Field of view

VR HMD environment is different from ordinary vision life because the visual field is reduced due to the lens range [11]. Because binocular visual field is a range of monocular overlaps, the reduced monocular visual field is an important factor. Therefore, when using the VR HMD, the left and right eyes have a visual field of the lens range. The user can obtain the visual information of the VR contents only through the lens and the lens magnify the screen. When the screen is enlarged by the lens, the user can see only a part of the screen.

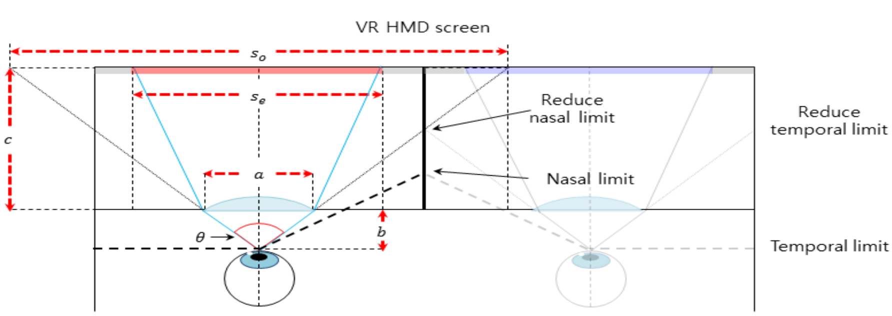


Figure 1. Human visual field reduced due to VR HMD lens

Figure 1 shows that the FOV is reduced by the VR HMD lens. Equation (1) shows the FOV when using the VR HMD.

$$\theta = 2 \times \ arctan(a/2b) \tag{1}$$

In Equation (1), θ Is a monocular FOV, a is lens diameter and b is a distance between lens and eye. The monocular FOV θ is same in left and right. The binocular visual field that the user perceives is obtained by substituting the values of the lens diameter a and the distance between the lens and the eye b into Equation 2 in order to obtain the screen size when the monocular FOV θ is used.

$$s_o = \frac{a \times (b+c)}{b} \tag{2}$$

In equation (2), a is lens diameter, b is distance between lens and eye, c is distance between lens and screen, and s_o is the screen size. The screen is enlarged by the lens magnification. The enlarged screen size can be obtained by substituting the screen size s_o into the equation (3) [12-13].

$$s_e = \frac{s_o}{\sqrt{M}} \tag{3}$$

In the equation (3), M is the magnification, s_o is the screen size, and s_e is the enlarged screen size [11]. The VR HMD FOV accepts an enlarged screen s_e with a monocular FOV θ. Table 2 shows the parameters of VR HMD FOV while using Google Cardboard and Samsung Galaxy Note 3.

Table 2. Parameter of VR HMD FOV obtained using Google Cardboard and Samsung Galaxy Note 3

Parameter	*Symbol*	*Value*
Monocular FOV	θ	92.34 °
Magnification	M	4.43
Lens diameter	a	25 mm
Eye distance (Lens-Eye)	b	12 mm
Screen distance (Lens- Screen)	c	36 mm
Screen size	s_o	100 mm
Enlarged screen size	s_e	47.51 mm

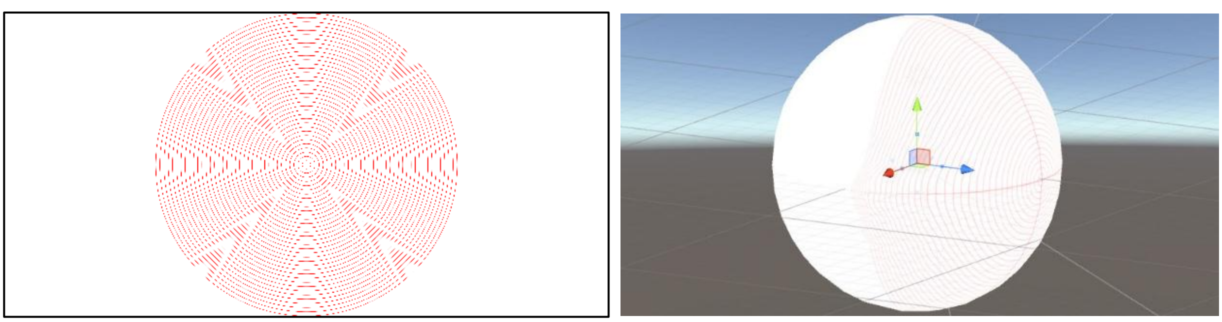
2.3 VR Contents Field of View

VR HMD contents are distorted according to the FOV provided by the vitual camera in the application. Figure 2 (a) shows the size when the highlighted object is in the center, and Figure 2 (b) shows the size when the same object is outer.

(a) (b)

Figure 2. Distortion occurred by virtual camera FOV
(a) Center (b) Outer

Figure 3 shows an experimental image for the measurement of the FOV distortion. Figure 3 (a) is a concentric circle image of 180 ° of horizontal FOV drawn in 5 ° increments. Figure 3 (b) shows an image of a concentric circular image in a spherical virtual reality space. The user sees the contents input through the virtual camera located inside the spherical virtual reality space. The content is distorted according to the FOV of the virtual camera.

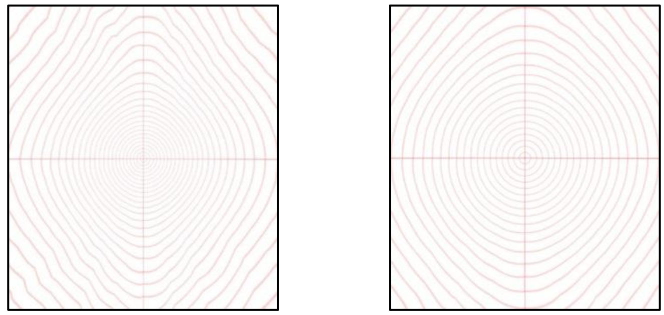


(a) (b)

Figure 3. Test images of VR FOV distortion
(a) Concentric circles image (b) Virtual environment image

Figure 4 shows the distorted image generated by the virtual camera FOV. Figure 4 (a) shows a distorted image at 120 ° FOV based on the human binocular visual field. Figure 4 (b) shows a distorted image at 90 ° FOV based on the VR HMD FOV. The distance between the concentric circles spreads outward of the image. It also increases as the FOV increases. In this distorted image, when the virtual camera rotates horizontally, the size of the surrounding object is decreased and the size of the centered object is incresed.

Changes in size of objects are important factors in human perception. This is because humans perceive depth by the size difference of an object they known. Distortion changes the size of the object seen by the user. Therefore, the depth information confusion that the user accepts is generated, and motion sickness is caused [14-15].



(a) (b)

Figure 4. Example of the content distorted images when angle of FOV is (a) 120 °and (b) 90 °

3. Experiment and Result

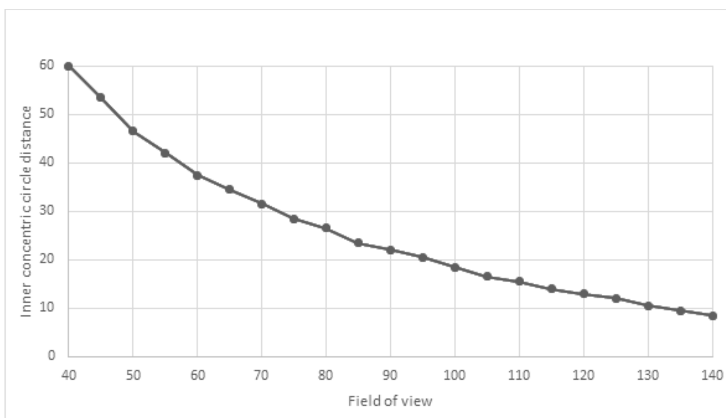
In order to measure the distortion according to the FOV of the VR content, we generated a distorted image of 5 ° intervals from 40 ° to 140 °. The distance between the inner and outer concentric circles is known. By calculating the ratio of the measured inner concentric circle to the outer concentric circle, we calculated the distortion rate. As the FOV increased, gap in the inner concentric circle decreased. During the variation in concentric circles form about 88~94%, there was no significant change in the distance variations with respect to the FOV. In case of outer concentric circles, the gap between circles decreased as the FOV increased. Their gap decreased by about 88 - 98%. There was no significant change in the outer concentric circles when the FOV changed from 85 - 105 °. When the FOV increased 105 °, their gap increased by about 100 - 109%. The ratio of the inner and outer concentric circles did not increase significantly until the FOV was 100 °. The distance ratio increased greatly when the FOV was 100 ° or more. Table 3 and Figure 5 show the variation of the inner and outer concentric gap.

Table 3. Variation in inner and outer concentric circle

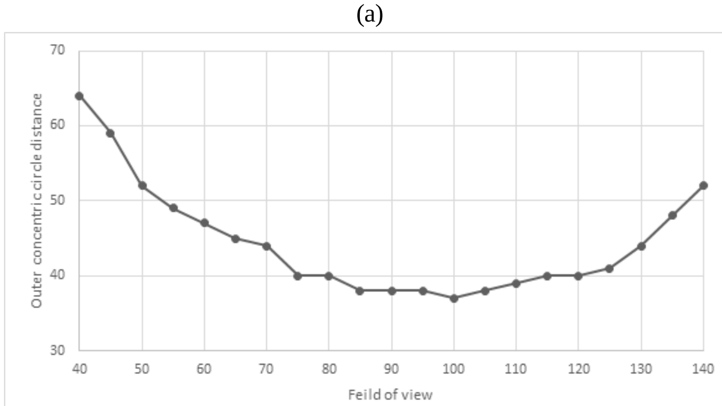
Field of view	*Inner concentric circle gap*	*Inner gap variation*	*Outer concentric circle gap*	*Outer distance gap*	*Concentric circles distance ratio*
70 °	31.5	-	44	-	1.40
75 °	28.5	90 %	40	90 %	1.40
80 °	26.5	93 %	40	100 %	1.51
85 °	23.5	89 %	38	95 %	1.62
90 °	22	94 %	38	100 %	1.73
95 °	20.5	93 %	38	100 %	1.85
100 °	18.5	90 %	37	97 %	2.00
105 °	16.5	89 %	38	103 %	2.30
110 °	15.5	94 %	39	103 %	2.52
115 °	14	90 %	40	103 %	2.86

120 °	13	93 %	40	100 %	3.08
125 °	12	92 %	41	103 %	3.42
130 °	10.5	88 %	44	107 %	4.19
135 °	9.5	90 %	48	109 %	5.05
140 °	8.5	89 %	52	108 %	6.12

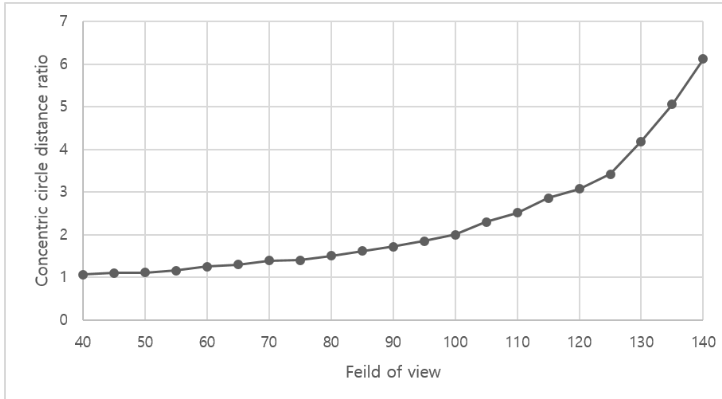
Experimental results show that as the FOV of the virtual camera decreases, the distortion of the inner and outer concentric circles also decreases. For small FOV, user can see only some part of the content through VR HMD. When the user rotates the head, a narrow FOV cause motion sickness. This is because the screen transition is so fast. The narrow FOV of a virtual camera produces a less distorted image, but differs greatly from a human visual field and is not effective in preventing motion sickness. It is effective to maintain a virtual camera FOV similar to the VR HMD FOV, and less distortion of the inner and outer concentric circles. For the FOV of the virtual camera from 90-100 ° minimized outer concentric distance. Therefore, the FOV from 90-100 ° in VR contents is considered to produce less motion sickness.



(a)



(b)



(c)

Figure 5. Variation in inner and outer concentric circle
(a) Inner concentric circle variation (b) Outer concentric circle variation (c) Concentric circle distance ratio

4. Conclusion

In this paper, we studied the distortion and FOV in VR HMD based contents as follows. First, we analyze parameters for FOV of VR HMD. Second, we created contents for the measurement of distortion occurred in VR contents. Third, we analyzed the distorted contents and proved the appropriate FOV of VR contents.

The results of this study will enable the development of high quality VR contents with minimum motion sickness. This study is expected to be applied not only to content production but also to optometry and vision therapy using VR HMD.

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