

39.3 Hyper-reality Head Dome Projector™ (HDP) for future displays

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Abstract

In this paper, we developed a novel hyperreality display called the Head Dome Projector (HDP). The HDP is a head-mounted display consisting of a dome-shaped screen with a very small radius of 40 cm, a mobile projector with ultra-wide projection lens and LED light sources. The main feature of the HDP is very wide viewing angle of 160 degrees horizontally by 120 degrees vertically comparable to the human visual field of view without head tracking and 360 degrees by 360 degrees with head tracking. According to our subjective evaluation comparing the HDP with a flat-panel display (FPD), the HDP realizes hyperreality 2.5 points higher than that realized by an FPD in the case of ± 5 level evaluation for HD motion images

1. Introduction

CAVE [1] and CyberDome Display [2] are well-known immersive hyperreality or virtual reality displays. However, in order to make such immersive displays, a large space of the order of one room is required, and so they have yet to be commercialized for the home-use or personal-use markets.

In order to make displays compact and personal, a head-mounted type display (HMD) has already been developed and commercialized. However, the HMD does not achieve immersion because of the small viewing angle of less than 30 degrees

On the other hand, compact mobile projectors with RGB LED light sources have recently been developed and commercialized [3]. They have certain advantages, such as wide color gamut, compactness and environmentally friendly characteristics, but their efficiency is insufficient for projection TV with high intensity or mobile use under bright illumination.

In order to achieve a compact and wide viewing hyperreality dome projector for personal use, taking advantage of the compactness and wide color gamut of LED light sources, we have already developed a new concept of a hyper-reality head-mounted display called head dome projector with a curved screen and compact LED projector [4]. It had a horizontally 115 degrees and vertically 80 degrees. We have improved not only the field of view to wider than 160 degrees horizontally, but also the central display resolution to 1.5 times higher than that of the conventional method by using pixel shift technology[5][6][7].

In this paper, we introduce the history of the hyper-reality HDP technologies and discuss the importance of the hyper-reality performance for the future display technologies.

2. Head Dome Projector (HDP) Concept

Figure 1 shows our proposed concept of the HDP.

The HDP mainly consists of a curved screen, a compact projector and a head tracking technology. In addition, since the HDP is completely separated from the external world by using a helmet-like case including a curved screen, it is uninfluenced by circumference illumination but increases the feeling of immersion.

The main features of the HDP are as follows.

- (1) Compact and wide viewing of higher than 160 degrees comparable to the human visual field of view by means of a curved screen and wide viewing compact projector
- (2) Motion parallax by using head tracking technology realizing a 360-degrees viewing
- (3) Wide color gamut by means of RGB LED light

Taking advantage of these features, our target is a personal-uses hyperreality display and developed HDP performances are shown in Figure 2, compared with those of other immersive displays.

3 Experiments for designing HDP

3.1 Screen shape and size

The HDP concept is based on our assumption that a small dome shaped screen is the best solution for realizing a personal immersive HMD. To confirm that assumption, we performed some experiments related to screen shapes and sizes.

Figure 3 shows the evaluation system with various viewing distances, screen shapes and sizes. Figure 4 shows the results of objective evaluations. It indicates that a dome-shaped screen is the best for achieving a hyperreality because hyperreality of small dome screen with a 40 cm diameter is higher than or comparable to that of the larger dome screens with a 60 and a 100 cm diameter. Regarding the disadvantages of a small screen, fatigue is expected to increase. However, in the case of a dome screen, fatigue at shorter distance is comparable to that at longer distance, although the viewing distance is shorter. It confirms that the HDP concept implemented with a small dome screen of 40cm is very useful for HMD-type personal immersive displays.

3.2 Vertical and horizontal viewing angle

Immersion and hyperreality are mainly determined by viewing angle [8]. Therefore, in the next experiment, required vertical and horizontal viewing angle were evaluated and determined. Figures 5 and 6 show the results. Figure 5 indicates that the required vertical

viewing angle is different between upper and lower, depending on human visual characteristics. The required upper viewing angle is larger than 50 degrees and the lower one is larger than 70 degrees in the condition that evaluation score exceeds level 4.5.

Figure 6 indicates that the required horizontal viewing angle is larger than 150 degrees in the same condition and hyperreality of a dome system with 150-degree viewing is 2 points higher than that of an HD system with 30-degree viewing..

3.2 Intensity, contrast and color gamut

HDP is completely separated from the external world. Therefore, viewing illumination condition is almost the same as that for movies. For a movie, the required maximum intensity is 41~75cd/m²(SMPTE 196M). Film contrast and color gamut are from 1000 to 1500 and NTSC, respectively.

4 HDP Prototype

The HDP prototype design is shown in Fig.7. Figure 8 shows a displayed image on the dome-shaped screen. Table 1 shows the performances of the HDP prototype. Figure 9 shows hyper-reality performance of the HDP with 160 degrees horizontal field of view. Table 1 indicates that obtained performances, with the exception of intensity, meet the specifications. Although intensity was less than half the specification because of the focus on compactness, it is sufficient for immersive gaming. Figure 10 shows a concept prototype of the HDP. Using head tracking technology, 360-degree motion images are obtained.

5 Conclusions

We developed a novel hyperreality display called the Head Dome Projector (HDP). The HDP is a head-mounted display consisting of a dome-shaped screen with a diameter of 40 cm, a mobile projector with ultra-wide projection lens and LED light sources. The main feature of the HDP is very wide viewing angle of 160 degrees horizontally by 120 degrees vertically without head tracking and 360 degrees by 360 degrees with head tracking. According to our objective evaluation comparing the HDP with a flat-panel display (FPD), the HDP realizes hyperreality 2.5 points

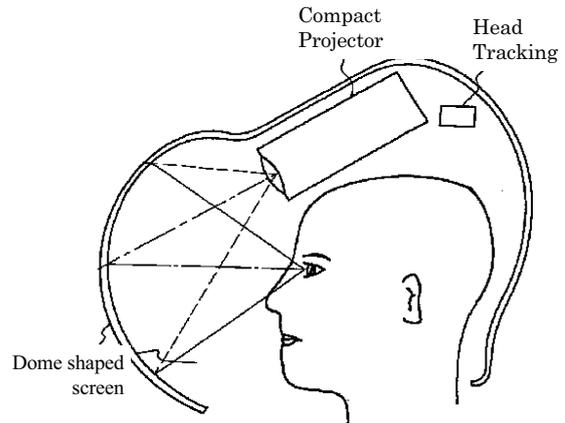


Figure 1 New Concept of Head Dome Projector (HDP)

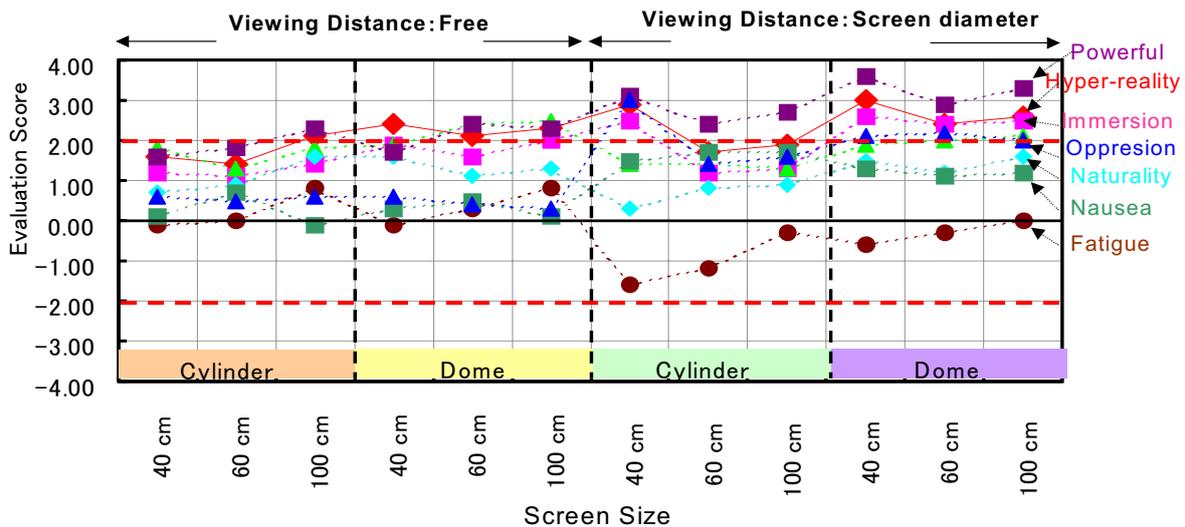


Figure 4 Subjective evaluations of screen shape and size

evaluation for HD motion

	CyberDome	SpiriDome 800	Head Dome Projector
Visual Angle	110°θ * 90°, degrees	360 degree with Head tracking	360 degree with head tracking (160°x20)
Dome Screen Size (Diameter) Display Weight	1800mm 260 kg	900mm 60 kg	400mm 2.8 kg: light
Resolution	1280*1024 (SXGA) Multi-PJ (2 PJ)	1920*1080 Multi-PJ (2 PJ)	1200*900 HD-Resolution Single-PJ
Required Space	Large	Large	Small (Head Mounted Type)
Brightness & Power	1500lm But High Power	500lm But High Power	15lm/W Low Power LED 15 cd/m ² on dome screen
CR	Open System Low Contrast	Open System Low Contrast	Completely enclosed system High Contrast≈1500
System Cost	High	High	Low
Total	△	○	●

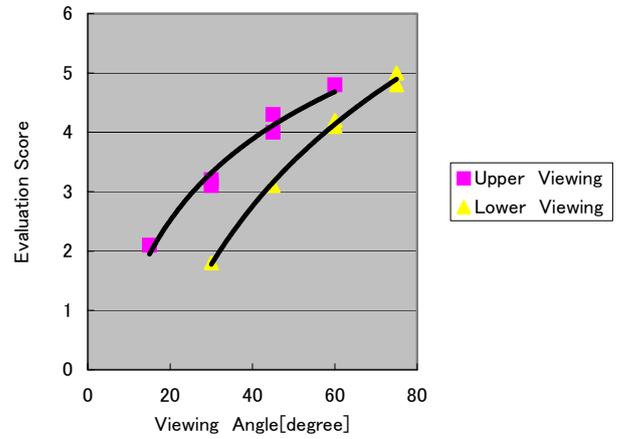


Figure 5. Vertical viewing evaluations

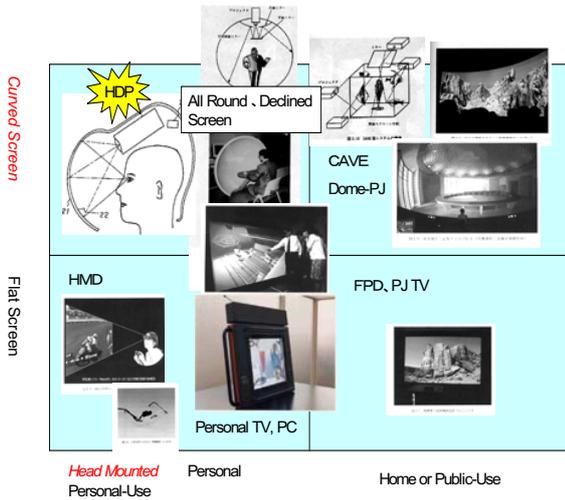


Figure 2. Targets and performances of the Head Dome Projector (HDP)

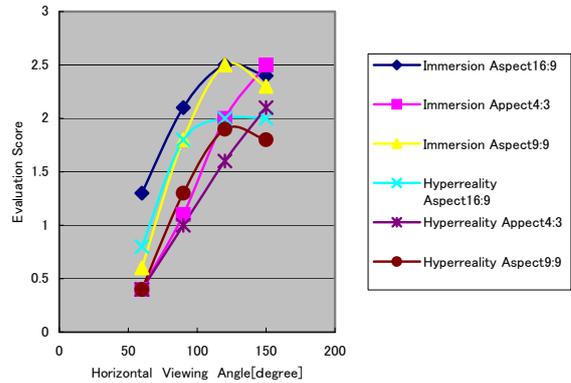


Figure 6. Horizontal viewing evaluations

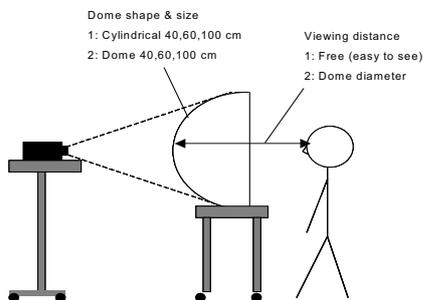


Figure 3. Experimental system for HDP parameters

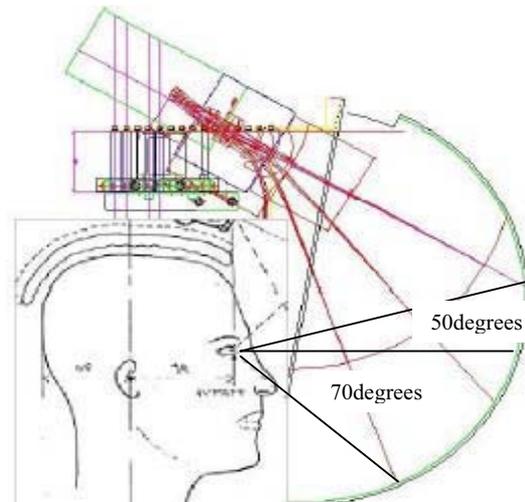


Figure 7. Overview of the designed HDP

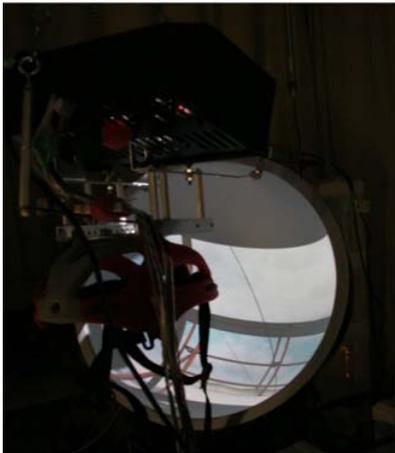


Figure 8 Image displayed on dome screen

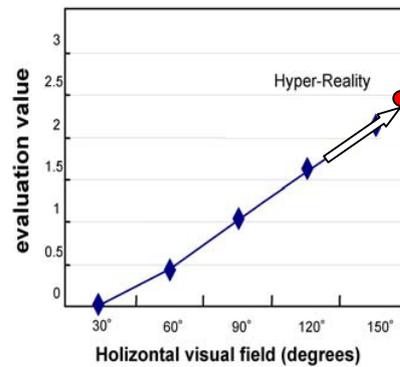


Figure 9 Hyper-reality performance of the HDP with 160 degrees field of view



Figure 10 Head Dome Projector (HDP)

Table 1 Performance of HDP prototype

	Target	Prototype
Viewing angle [degree]	±75(H)	±80(H)
	50(upper)	50(upper) 、 70(lower)
	70(lower)	
Intensity [nit]	>41	15
Resolution	1280~1920(H)	1200(H)
	720~1080(V)	900(V)
Contast	1000-1500	1500
Weight [kg]	<2	2.8

5. References

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