# Impressive 3D CG technologies for automotive HUDs with wide FOV

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## Abstract

***We have developed various kinds of 3D CG technologies, moving shadow method (MSM) to improve the Field of View (FOV) and Infoball concept to achieve higher visibility of displayed images for the monocular HUD. As a results, we successfully realized novel 3D-HUD system with wide FOV and high visibility.***

## 1. Introduction

We have been focusing on personalized immersive display for the next generation display for more than 10 years, as shown in Fig. 1.

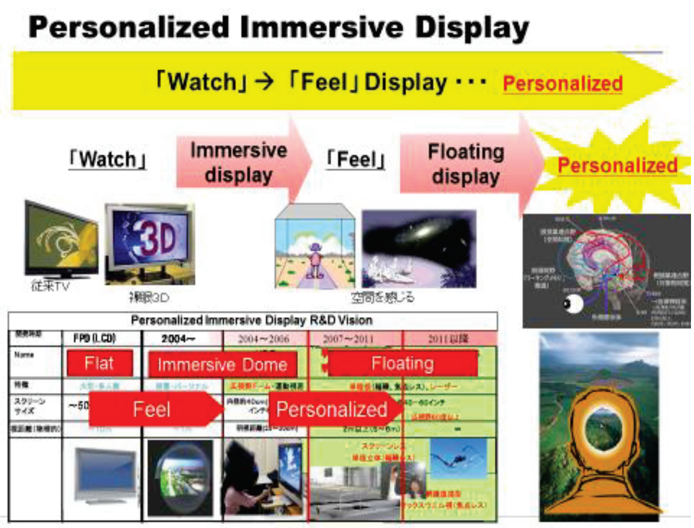



**Figure 1. Next generation personalized display technology**

In order to achieve a compact and wide viewing hyper-reality dome projector for personal use, and taking advantage of the compact and wide color gamut of LED light sources, we have developed a new concept of a hyper-reality head-mounted display called head dome projector (HDP) with a curved screen and compact LED projector with wider FOV than 160 degrees [1][2].

On the other hand, as next generation personal see-through type AR displays, a monocular Head-Up Display (HUD) has been developed [3]-[5], as shown in Fig.2.

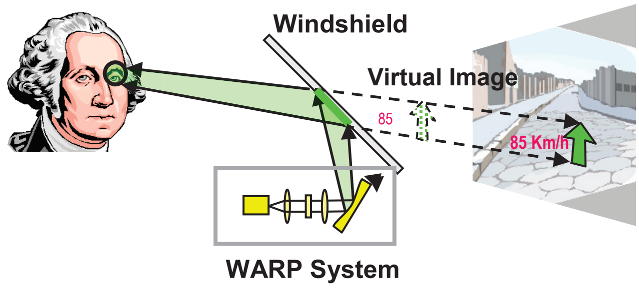



**Figure 2. Monocular HUD concept: WARP**

Monocular HUD is expected to offer the advantage of faster perception speed. In the case of usual binocular HUD, when a far point is viewed, the HUD image becomes blurred due to the location difference between HUD image and real background. This is double vision caused by binocular parallax (Figure 3). In the case of monocular HUD, the HUD image can be clearly seen irrespective of any fixed point. The monocular HUD allows the minimum accommodation time and the maximum perception speed.

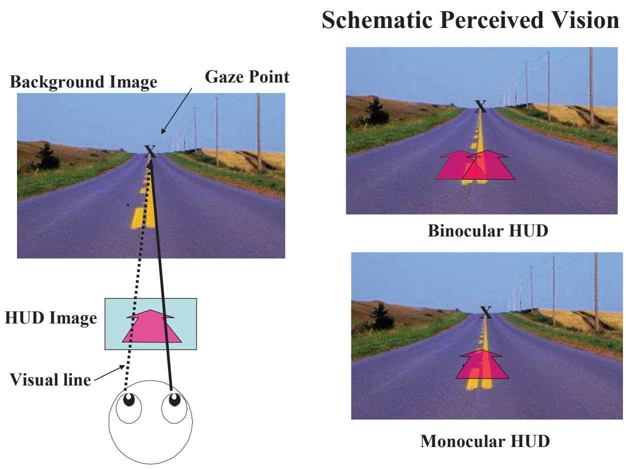



**Figure 3. Schematic View of Binocular and Monocular HUD Images.**

## 2. Integration of 3D-CG technologies on the monocular HUD

In case of monocular HUD, we can easily control the depth and visibility by using 3D-CG technologies. Therefore, integration of 3D-CG technologies on monocular HUD is very important for improving the hardware performance.

The dynamic perspective method uses a size and a position of an object image as depth cues that are important factors in psychology [5][6]. An example of an object image is an arrow for navigation. When we want users to perceive near position, the object image on the monocular HUD is displayed bigger and lower. When we want users to perceive far position, the object image is displayed smaller and higher as the object image moves to the far position. Examples of object images based on the dynamic perspective method are shown in Figure 3. The dynamic perspective method achieved a depth perception position of 120 [m] within an error of 30%.

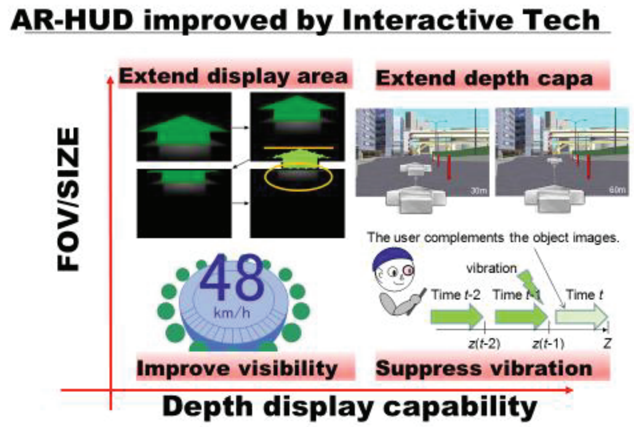



**Figure 4. Monocular 3D CG Technologies for wide FOV and high visibility**

2-1: Subjective evaluation

At first, we made subjective evaluation process consisting of 4 process to extract main factors of CG contents for HUDs, as shown in Fig.5.

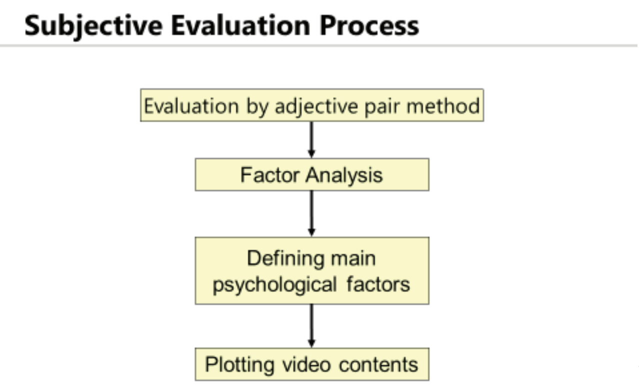



**Figure 5. Subjective Evaluation Process of displayed CG contents for HUDs**

(1) Evaluation by adjective pair method

This process is shown in Fig.6. We have 14 evaluation contents, 16 adjective pair evaluations with 7 scores done by 5 subjects.

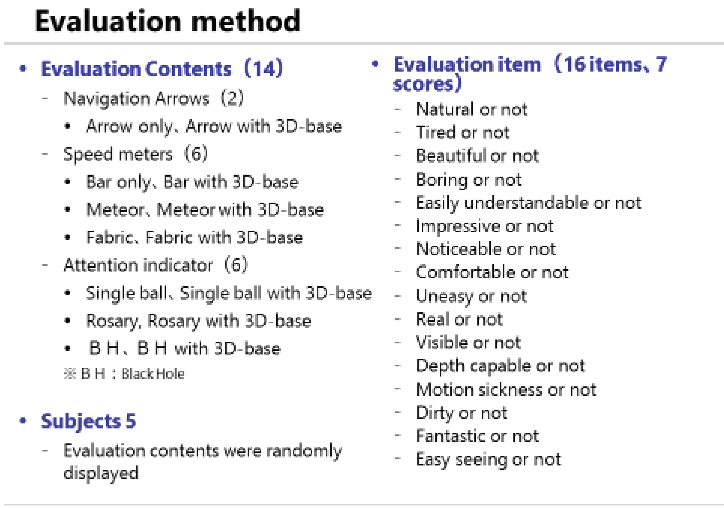



**Figure 6. Evaluation method of displayed CG contents for HUDs**

(2) Factor analysis

After evaluation, we made factor analysis to pick up main factors for the CG contents as shown in Fig.7.

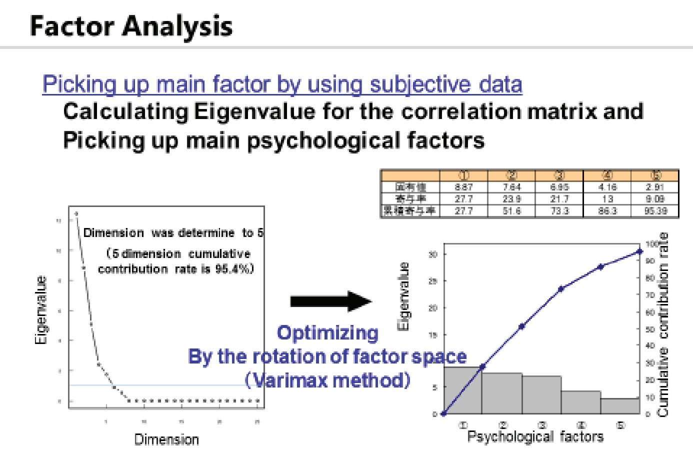



**Figure 7. Factor analysis of displayed CG contents for HUDs**

(3) Defining main psychological factors

After factor analysis, we picked up 5 main factors, as shown in Fig.8.

① Visibility , ②Impression , ③Discomfort , ④Sharpness

⑤Smoothness

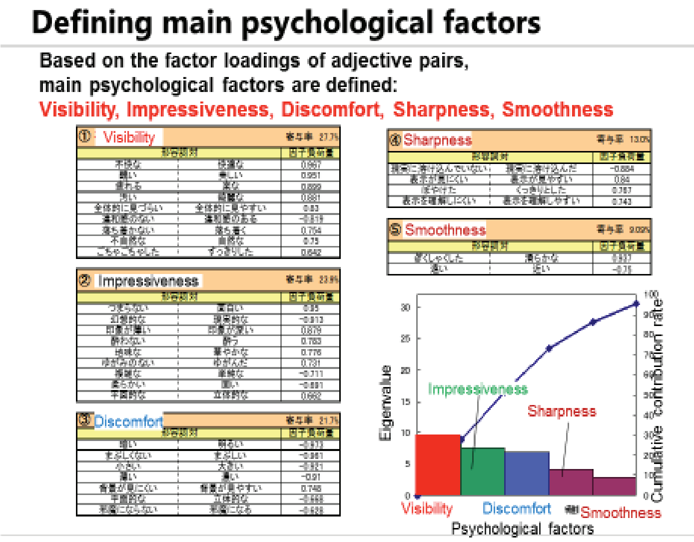



**Figure 8. Defining main psychological factors of displayed CG contents for HUDs**

(4)Plotting CG contents in the most important two factors: Visibility and impressiveness

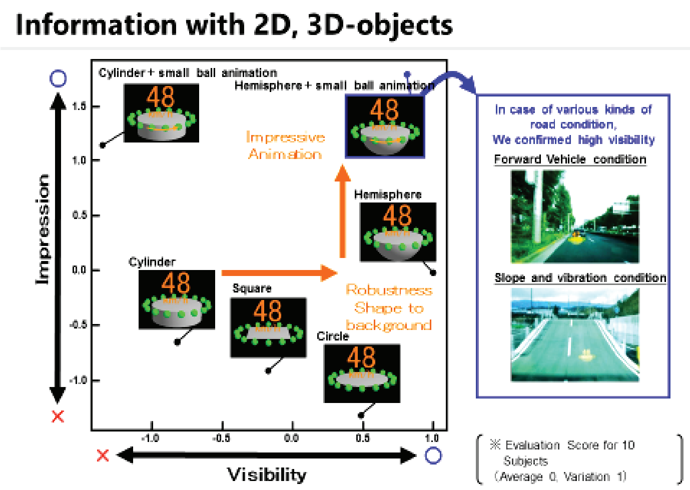



**Figure 9. Plotting displayed CG contents for HUDs at two axes of main factors**

Figure 9 shows CG contents for HUDs plotted in the visibility vs impressiveness axes. We picked up information display content based on a spherical object as most impressive CG contents for HUDs, FOBIC(Floating Object Based Information Creation), shown in Fig.10. The base object, hemispherical object, can be located naturally as floating object so that it can be overlapped naturally on any real background, such as road or sky. That is the main reason why FOBIC concept is most suitable to make AR-HUD contents with high impression and visibility.

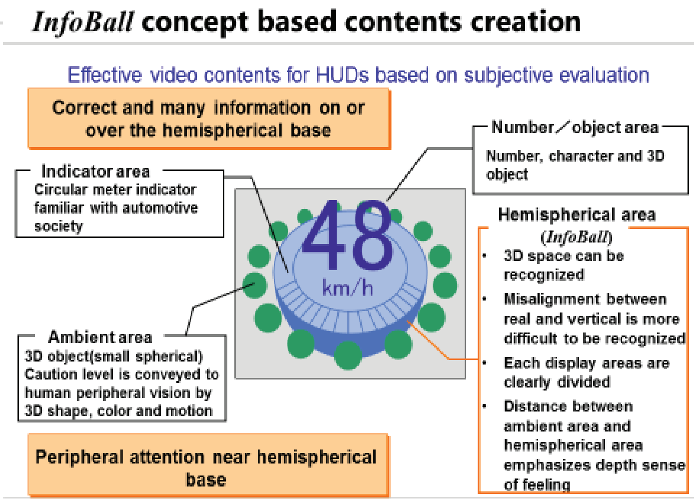



**Figure 10. Our proposed impressive CG contents for HUDs**

2-2: 3D-CG display method to extend display area

The tradeoff between wide FOV and compact HUD size have been one of the most difficult issues to be solved. Therefore, we have developed novel concept of flesnel reflector [7]. We developed another solution called moving shadow method (MSM) by using 3D-CG technologies, as shown in Fig. 11.

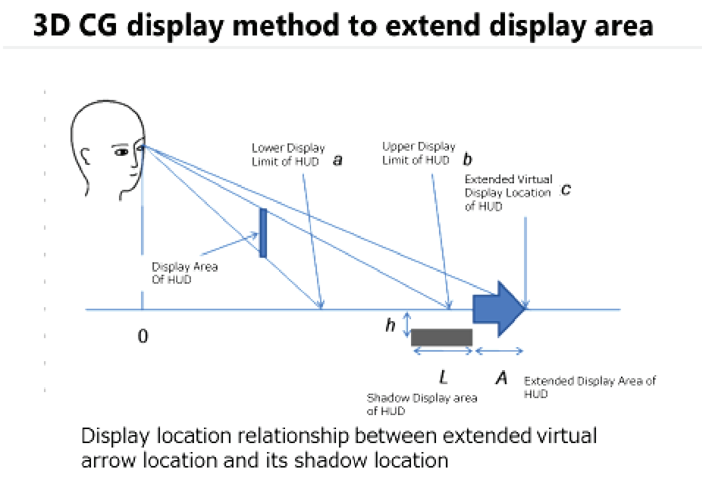
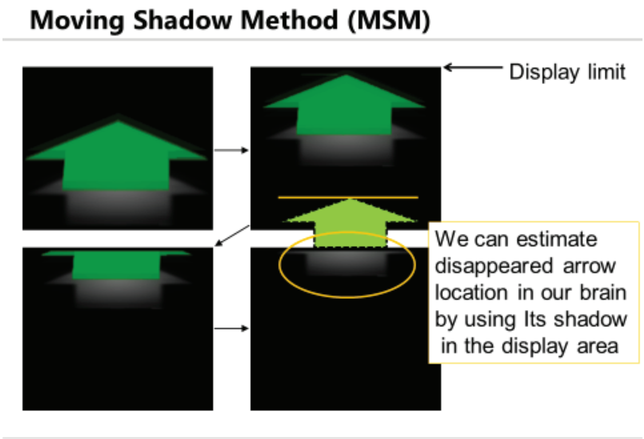
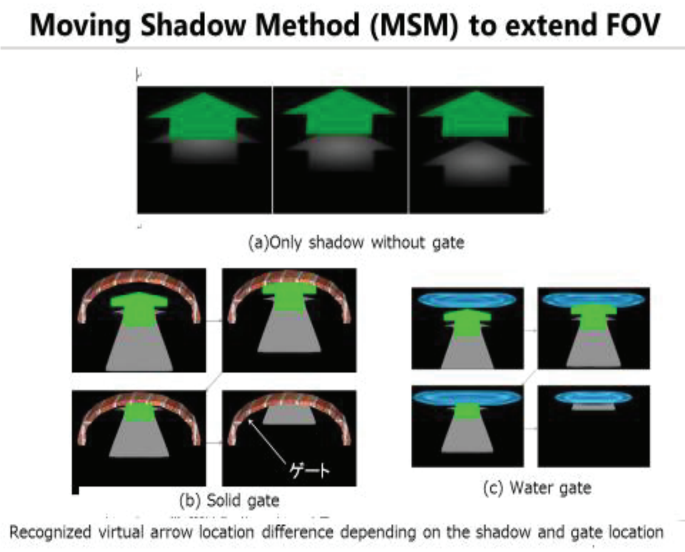



**Figure 11. 3D CG display method to extend display area for HUDs**

It is common that the displayed information is limited in the HUD area. However, in the case of moving objects, if the shadow of the objects remain in the HUD area, we can estimate disappeared object location in our brain. Therefore, by using 3D-CG shadow, we can extend the HUD area, as shown in Fig.12.




(a) Principle of MSM




(b) Various kinds of MSM

**Figure 12. Our proposed Moving Shadow Method (MSM), as an example of 3D CG display method to extend display area for HUDs**

Figure 13 shows the result of HUD area extention by using MSM. 1.25 times extention as depth of 40m to 50m has been achieved.

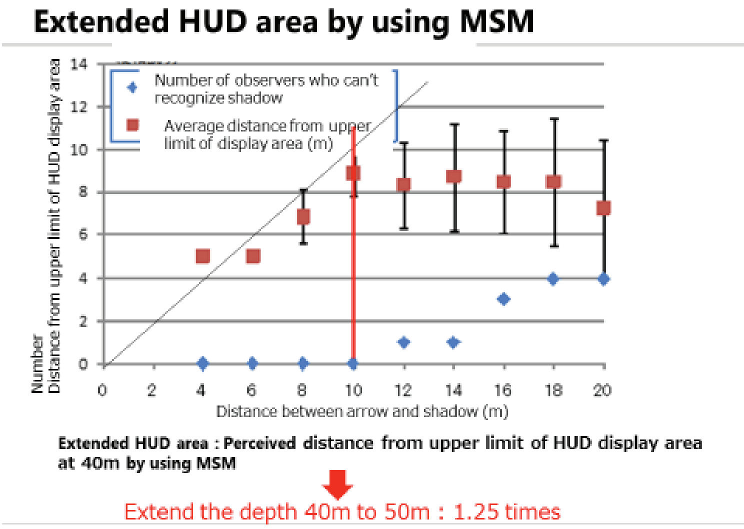



**Figure 13. Results of extended display area by using the MSM**

## 3. Conclusions

We have developed novel 3D-CG technologies for monocular HUD.

(1)Main psychological factors for monocular HUD contents were extracted. : ①Visibility , ②Impression , ③Discomfort , ④Sharpness, ⑤Smoothness

(2)FOBIC concept to create 3D-CG contents for monocular HUD was proposed and as one of the examples, InfoBall content was developed.

(3)HUD area extension: 1.25 times extention as depth of 40m to 50m has been achieved by using moving shadow method (MSM).

## 4. References


[1] H. Okumura et al., Proc. of SID'06, 72.4, 2006

[2] A. Hotta et al., Proc. of the SPIE, Vol.6490, pp. 64901R, 2007

[3] H. Okumura, et al., Proc. of Euro display 09, P24, 2009

[4] T. Sasaki, et al., "Hyper-realistic Display for Automotive Application", proc. of SID 2010, 64-2, 2010

[5] Takashi Sasaki et al., Novel Depth Perception Controllable Method of WARP Under Real Space Condition. In Proc. of SID2011, pp244–247, 2011.

[6] Harry Edwin Burton. The optics of Euclid. In Journal of the Optical Society of America, vol. 35, no. 5, pp 357–372, 1945.

[7] H. Okumura, et.al., "Wide field of view Optical Combiner for Augmented Reality" , Proc. of ICCE2018, pp459-462、2018