Distortionless optimal stereoscopic image condition considering general viewing distance in the TV condition

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Abstract

Large distortion is made by toed-in camera configuration in the TV condition that has short viewing distance, when the gaze position of a stereoscopic image coincides with that of real space. Therefore, in the TV condition, we confirmed that the proper camera configuration is the modified parallel configuration, and found distortionless optimal stereoscopic image condition using this camera configuration.

1. Introduction

In the stereoscopic display, the toed-in configuration, which is one of the ways to get an image, is being used more popular because it is similar to human visual system. But, depth plane curvature is occurred by this configuration due to the camera convergence.[1] In order to remove this geometrical distortion, we use modified parallel camera configuration which describes the toed-in configuration through parallel configuration. This configuration has disadvantages which need a shift of CCD at stereo camera and see artificial image which is dissimilar to human visual system. Generally, convergence position of stereo camera is interesting position of an observer. And this convergence position is on the display screen. Specially, short convergence point is made due to viewing distance in the TV condition, when a stereoscopic image is the same size as real space and the gaze position of stereoscopic image coincides with gaze position of real space.

In this paper, we found the camera configuration suitable to reconstruction of stereoscopic image in the TV condition and also distortionless optimal image condition through this suitable camera configuration. And it is verified by a numerical simulation method.

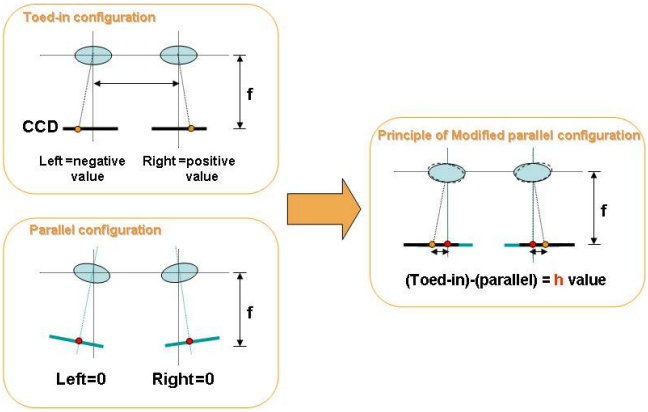


Fig. 1. Stereoscopic camera configurations

2. Simulation condition

The Equation of stereoscopic image space which is seen by observer is as follows. At this time, the equation is different according to stereoscopic camera configuration.

Modified parallel camera configuration :

$$X_i = \frac{MfeX_o}{Z_o(e-2Mh)+Mfc} \qquad \left(\therefore h = \frac{fc}{2C_d}\right) \quad (1)$$

$$Z_i = \frac{V_d eZ_o}{Z_o(e-2Mh)+Mfc}$$

Toed-in camera configuration :

$$X_i = \frac{Mfe\left\{\tan\left[\arctan\left(\frac{2X_o+c}{2Z_o}\right)-\beta\right]-\tan\left[\arctan\left(\frac{-2X_o+c}{2Z_o}\right)-\beta\right]\right\}}{2e+2Mf\left\{\tan\left[\arctan\left(\frac{-2X_o+c}{2Z_o}\right)-\beta\right]+\tan\left[\arctan\left(\frac{2X_o+c}{2Z_o}\right)-\beta\right]\right\}} \quad (2)$$

$$Z_i = \frac{V_d e}{e+Mf\left\{\tan\left[\arctan\left(\frac{-2X_o+c}{2Z_o}\right)-\beta\right]+\tan\left[\arctan\left(\frac{2X_o+c}{2Z_o}\right)-\beta\right]\right\}}$$

Here, X_o, Z_o are each width and depth position of real space. e is binocular distance. c is camera interval. f is camera focal length. V_d is viewing distance. C_d is camera convergence distance. β is camera convergence angle. M is magnification between camera CCD size and TV size. And h is CCD offset value which corresponds to convergence angle β in the modified parallel camera configuration. We simulated through Eq. (1), (2)

In order to compare toed-in with modified parallel camera configuration in our simulation, the same simulation condition except the camera convergence angle and camera CCD offset value is used to our simulation. TABLE 1. Shows our simulation condition.

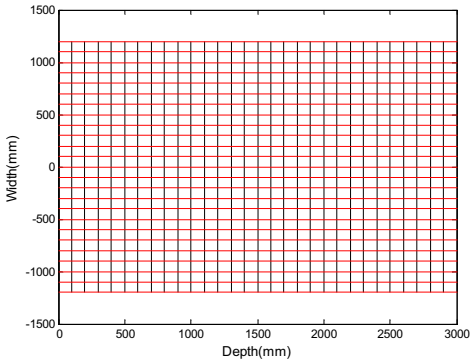
TABLE 1. Used parameters and its values in simulation

Parameter		Value
Camera condition	Interval	65mm
	CCD size	36mm
	Focal length	35mm
	Convergence distance	equal to viewing distance
	Convergence Angle	1.8791 degree
	CCD offset	1.1483mm
Viewing condition	Binocular distance	65mm
	Viewing distance	1.5 times of TV diagonal size
	TV size	26inch

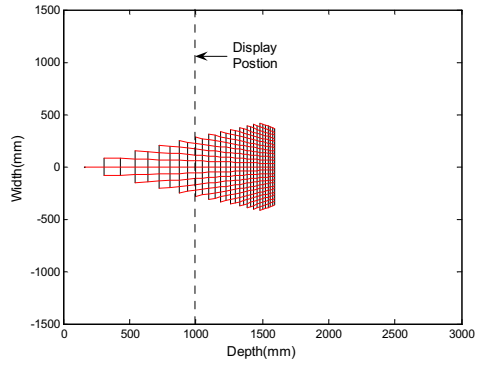
In the TABLE 1., we applied that observer's viewing distance is 1.5 times of display diagonal size, which is the proper viewing distance to consider image quality and immersive feel. Generally, proper viewing distance according to TV (16:9 wide-screen) size is 1.5~3 times of display diagonal size.[2] And the camera convergence distance is the same observer's viewing distance in order to get stereoscopic image of real scale.

3. Results and discussion

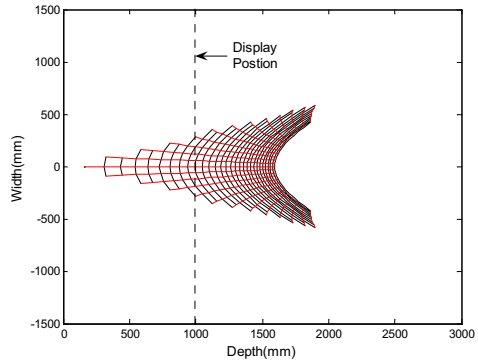
First, we checked the image distortion about depth and width through toed-in and modified parallel camera configuration in 26 inch TV condition.



(a) Object space (2.4m * 3m)



(b) Result of modified parallel camera configuration



(c) Result of toed-in camera configuration

Fig. 2. Used object space in simulation and the simulation results

Fig. 2. shows the used object space in simulation and the simulation results about image distortion. Fig. 2. (a) shows used object space in our simulation. The object space is width 2.4m and depth 3m. And the expressed grid is 10cm interval(width and depth). Fig.

2. (b) is result of modified parallel camera configuration. Here, dotted line is the TV position. In the figure, we can see image distortion of depth direction which is only depth non-linearity. Fig. 2. (c) shows results of toed-in camera configuration. In the figure, we can see not only depth non-linearity but also large depth plane curvature in depth image distortion. Specially, we can know that effect of depth plane curvature is big. This is caused by convergence angle of toed-in camera which is big in the TV condition because of short viewing distance.

We compare 26 inch TV with other size display devices which are 42, 50, 65 inch TV and cinema screen with horizontal size 16m about effect of depth plane curvature in the same condition of above simulation condition(TABLE 1.) Fig. 3. shows the image distortion (depth plane error) about acquired 3m depth plane with width 2.4m through the toed-in camera configuration. In Fig. 3., we can confirm that the smaller a display size is, the larger convergence angle of camera becomes, so the distortion is seen large. As a result, in the large display condition, toed-in camera configuration which is similar to human visual system has an advantage on the other hand modified parallel camera configuration has an advantage in the TV condition. Therefore, we can find that the camera configuration has to be the modified parallel configuration in the TV condition.

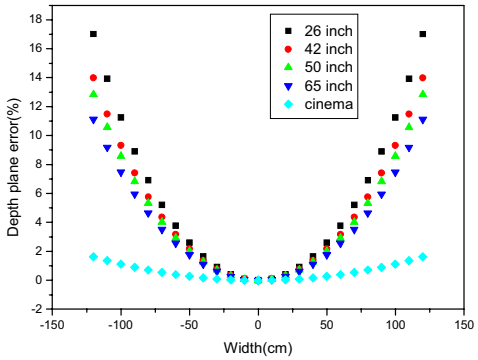


Fig. 3. Depth plane curvature about 3m depth of toed-in configuration in each TV size and cinema condition

Although depth plane curvature can be removed by the modified parallel configuration, depth non-linearity in image space can be removed by just special condition.[3] Special condition is e=2Mh in Eq. (1). This special condition is made by variation of camera condition with the fixed display viewing condition. And if V=Mf in Eq. (1), image space equals real space(Z_i=Z_o). As a result, in order to reconstruct the image space which has distortionless real space scale, CCD offset value of modified parallel configuration which is corresponding with camera convergence angle and camera focal length must be just adjusted. When the general TV viewing condition is considered in the case of 26inch TV, the stereoscopic image of distortionless real scale can be obtained by special condition, which is that CCD offset is 2.033mm and the camera focal length is 61.957mm. Fig. 4. shows the used object space in simulation and the simulation result through optimal image condition in 26inch TV. In the Fig. 4., we can confirm that the image space reconstructs as distortionless real scale.

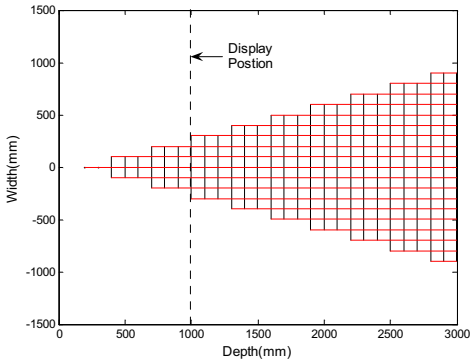
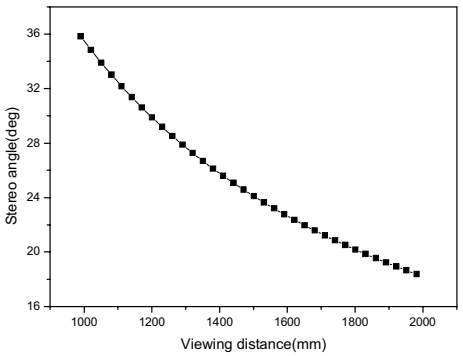
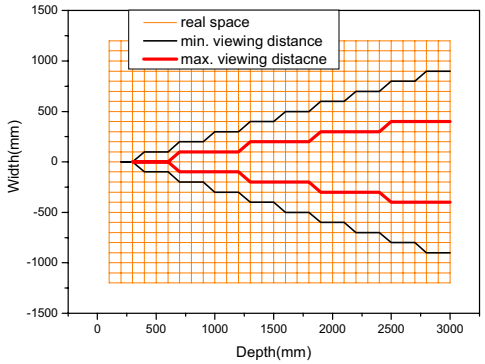


Fig. 4. Simulation result about image space in 26 inch TV through distortionless optimal image condition

Also Fig. 5. shows the stereoscopic image area according to variation of viewing distance in proper TV viewing interval. In this Figure, we confirm that the shorter viewing distance is, the wider reconstructed area is. Therefore, an observer's viewing distance is kept minimum viewing distance in order to get larger 3D information of real scale in permitted viewing distance interval.



(a) Viewing angle according to variation of viewing distance in proper viewing interval



(b) Variation of stereoscopic image area according to maximum and minimum viewing distance

Fig. 5. Stereoscopic image area according to variation of an observer's viewing distance in 26 inch TV

4. Conclusion

In the TV condition that considers general viewing distance, we found the proper stereoscopic camera configuration for embodiment of optimal image condition through our simulation. As a result, the proper camera configuration is the modified parallel camera configuration in stereoscopic TV condition. Through this camera configuration, we showed simulation result for optimal image condition which is distortionless real scale image condition. In this optimal image condition, the observer can feel perfect stereoscopic effect without the image distortion.

5. Acknowledgments

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6. References

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