The correct depth representation in displayed space at stereoscopy

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Abstract

We proposed the method to present corrected depth cue to an observer by stereoscopic display. It was performed in sequence that designing the displayed space having a constant interval of depth and then defining the object space which had considered to an environment of display and based on computer graphics. Consequently, we had performed a different process of reported existing methods distinctively and taken the result which correctly designed depth cue having linearity whatever various sizes of display would be used.

1. Introduction

Nowadays, stereoscopy is one of the most powerful methods for presenting depth cue to an observer and it has been widely used in places such demanded simple depth cue as entertainment and education. Also, it had the effectiveness has been turned out by reported papers [1]. However, the existing stereoscopy is restricted to use when it was applied to the places which had demanded more corrected depth cue such fields of medical, military and advanced education. Since it has been reported some disadvantages which as non-linearity depth and distorted image. They will be generating when the factors such as stereo camera alignments, size of display and viewing distances would be changed [1]. Generally, to provide depth cue to an observer by stereoscopic display, the stereoscopy has been performed in sequence that firstly, taking the information of disparity to an object distance from the position of center of camera to the object by stereo camera system and then secondly, displaying the stereogram which was made by stereo image with adequate types of 3D display, and presenting the depth-cue to an observer. The nonlinear depth representation and the distorted image are main problems interrupting to present the designed depth of the object space to an observer, and these problems are defined and described at references. [2,3] To solve one of problems which as the non-linearity depth when a stereogram was displayed, the existing methods have been taken the way controlling the size of display and the viewing distance representative. In this way, however, the sizes of a plane at the object space and the display must be satisfied equal to their scales to remove the problem. The way is well known to us as orthostereoscopy method to overcome depth non-linearity phenomena in process which embodying 3D depth cue to an observer.[3] The method has advantage that it can presents depth linearity correctly to an observer by displaying stereogram on a size of screen which was considered the relation of the distance between the screen and an observer. For this reason, orthostereoscopy has a number of adequate places such above mentioned the fields to provide a natural scene having corrected depth-cue to an observer whatever input source was constructed by any tools such a real camera or computer graphics. However it has a disadvantage in practically that if we want to recognize larger sense of a present by this method such a real scale of an apartment, mountain and a lake etc., the size of screen will be great to satisfy full of the field of view (FOV) of human eyes. Therefore, it is not adequate method to use in a scale of display such mobile, official and smaller displaying circumstances than maximum FOV, and moreover the object size must be restricted belong to the size of screen or display to present its original scale when it was displayed. For these reasons, the designed depth cue with real scale would be distorted to observer in case that was not satisfied to orthostereoscopy. If so that the displayed image satisfying orthostereoscopic constraint was just demagnified to the user demanded circumstances, for instance such official or mobile, an observer recognize depth cue having non-linearity

from the plane of display to each directions as front or rear. And the values of the ratio of the both directions of depth non-linearity are different because the inter-distance of human eyes is constant but the size of the stereogram to be demagnified relatively and that the matter will produces incorrect depth cues with both directions independently to an observer.[4]

In our investigation, we proposed the method as a solution to present corrected depth cue to an observer whatever the size of display was used in stereoscopy. Depth linearity was used as a tool for verifying the solution. The solution was performed in sequence process that firstly, designing the displayed space having a constant interval depth and then secondly, defining the object space based on computer graphics which had considered to the size of display. The stereogram was used to input source for presenting depth cue. It has included information of the object space due to the designated linearity depth. The object space was constructed based on computer graphics (CG) because CG able to make the object space freely.

2. Experimental

As we mentioned the our purpose in introduction, we tried to verify the proposal whatever types of camera alignments such as parallel or toed-in is used in stereoscopy. Figure 1 shows an expected result by existing method that the displayed image having depth non-linearity even if the object space had a stated interval was designed.

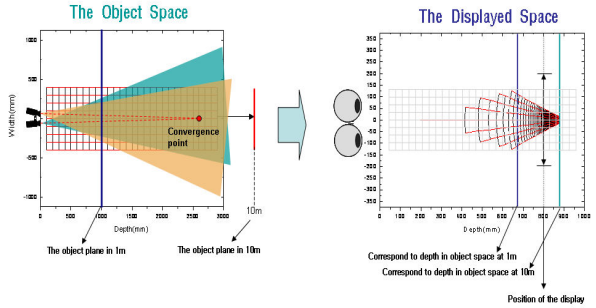

Figure 1. The non-linearity depth and distorted image by existing method

In the process, toed-in camera alignment is used to obtain the stereoimage and the range of the object space is considered 1m to10m standard for an camera position. And the constraints of the system are considered that the focal length of lens in camera had 35mm, the FOV of camera is 63 degree, the inter-distance of cameras had 65mm and the viewing distance to see the stereogram had 800mm. To compensate the displayed image having depth non-linearity, we constructed the object space that it is designed to take a stated interval by 50mm when it was displayed. And it was made up CG by MAYA graphic design program. To put it more concretely, when toed-in stereo camera alignment was used in the process, the designed object space had a curved depth and non-linearity intervals to the each object planes because a converged angle of toed-in stereo camera alignment affect to the former and a demagnified disparity in stereogram which is not satisfied orthstereoscopic constraint affect to the latter. Specially, the parallel type is only conformed to the latter. For these reasons, to present correct depth cue to an observer, we can redesign the object space having removed these considerations. Firstly, design the displayed space having a constant interval depth and then secondly, define the object space based on computer graphics which had considered to the size of display. Figure 2 shows the concept to our proposal to solving depth non-linearity problem.

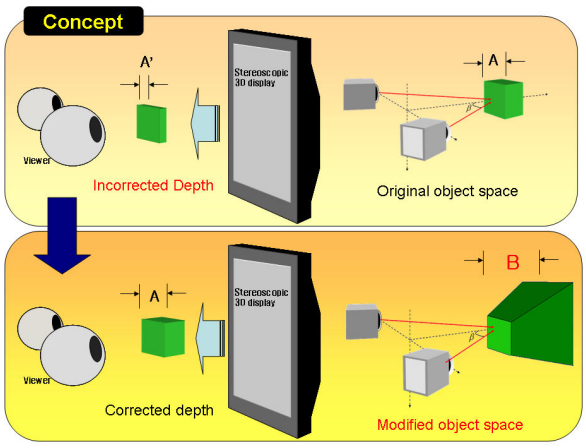

Figure 2. Schematic of our method to take corrected depth cue

Figure 3 shows the redesigned object space had considered a stated interval in the displayed space. To take theoretical values of the redesigned object space based on the linear depth cue in a displayed image are derived by equation (1), (2). The denotes in these equations have meaning that $X^{P}_{SL,SR}$ is the image coordinate of left (SL) and right (SR) in the stereogram on the display or screen which was extracted from an observer position, M is magnification ratio of the size between the display and the detector in camera, f is focal length of lens, β is convergence angle in toed-in type only, t is inter distance to the center of cameras. And X_O, Z_O are the coordinates of redesigned object space by our solution. Here R is switchable function (R=T : toed-in type,

R=P : parallel type) according to circumstance of stereo camera alignments. Additionally, disparity on the display was defined difference of the image coordinates of left and right, and the value of disparity is depended on depth cue of displayed object image. Since our solution is proposed as an inverse process comparing to the existing stereoscopic method. The investigation was performed by practical tests for 4 subjects and 19" stereo monitor was used.

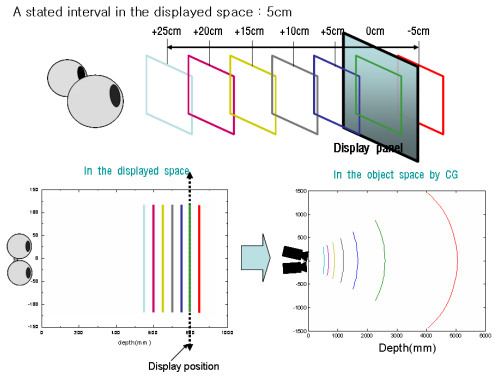

Figure 3. Transformed object space due to designed a stated interval

$$Z_O^R = \frac{t}{\tan\left(\left(\tan^{-1}\left[\frac{X_{SL}^R}{Mf}\right]+\beta\right)\right)+\tan\left(\left(\tan^{-1}\left[\frac{X_{SR}^R}{Mf}\right]+\beta\right)\right)} \quad (1)$$

$$X_O^R = \pm Z_O^R \tan\left(\tan^{-1}\left[\frac{X_{SL,SR}^R}{Mf}\right]+\beta\right) \mp \frac{1}{2} \quad (2)$$

3. Results and discussion

We calculated and verified the corrected depth cue having linearity in displayed space by our method. Since our method having the different way comparing to the existing methods, which is transforming the object space based on CG due to already designed the displayed space. In addition, we had taken good results whatever various sizes of display would be used. Table 1 and Figure 4 shows results of practical tests and the stereogram as input source made by our method. The data in table 1 is described only 4 cases of all practical data and the value in a round bracket has meaning that the distance was redesigned object space according to the upper values with non-bracket. The non-bracket value is desired depth cue in displayed space of the image. Denoted character as 'Behind' has meaning that the depth cue of the displayed object image was cannot practical experiment because the depth image was formed rear place of the display.

Table 1. Results of practical tests for 4 subjects

subjects / Designed space[mm] (Object space[mm])	Subject 1 Exp. Data[mm]	Subject 1 Exp. Data[mm]	Subject 1 Exp. Data[mm]	Subject 1 Exp. Data[mm]
+250 (546)	240	250	270	250
+200 (692)	180	200	220	200
+150 (894)	120	160	170	150
-50 (5053)	Behind	Behind	Behind	Behind

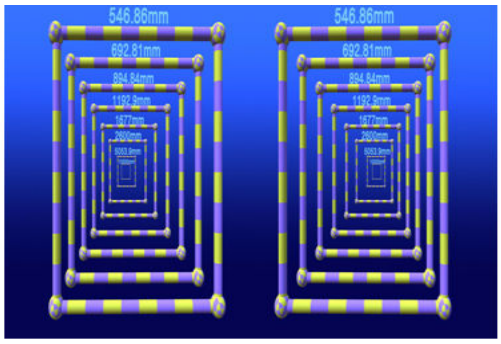

Figure 4. Stereogram made by our method

4. Summary

The non-linearity depth phenomena is one of the disturbing factors in stereoscopy to provide a nature depth cue as the real object space due to display size. Therefore, restricting or removing the factor is very important in stereoscopy. For this reason, we had proposed method that transforming the object space based on CG to the designed displayed space having a stated interval and taken good results which verified by practical test. We expect the result of our investigation will be helpful to embody correct depth cue whatever any stereoscopic circumstances will considered.

This work was supported by the IT R&D program of MKE/IITA. [2008-F-011-01], " Development of Next-Generation DTV Core Technology" and the Seoul Science Fellowship

5. References

1. T. Izumi(Supervisor), NHK Science and Technology Lab., Ohmsa, Tokyo, 1995, ch. 3, pp55-60.
2. A. Woods, Proc. SPIE V1915, pp36-48, 1993.
3. Jung-Young Son, SPIE ITCom'06, V6382-6
4. K. H. Lee, Hankook Kwanghak Hoeji, V18, N4, 2007.