A study on compensation of distorted 3D depth in the triple fresnel lenses floating image system

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Abstract

We proposed the method to take 3D image having correct depths to the front and rear directions when the stereogram was displayed to an observer through an optical system. Since the magnified stereogram by lenses was not given correct depth to an observer despite having the same magnified disparity. Consequently, we achieved our goal by relations of compensated disparities to both directions with magnification of lenses, viewing distance and base distance of viewer in AFIS.

1. Introduction

Generally, existing flat panel type of stereoscopic 3D display has a disadvantage that is impossible for physical interaction to rear depth cue when an object 3D image was displayed. Since the rear depth is located behind the display therefore an observer can not physically interaction with if. To overcome this problem, we designed the advanced floating image system(AFIS) that was composed by two systems which one is optical system offering pseudo 3D as floating depth to an observer from input image or object and the other is stereoscopic system generating front / rear depth cues at floated image plane from stereogram. However, although the rear depth able to serve physically interaction to an observer, but very important another problem in optical system was generated which is the distorted depth.

The distorted depths to the front / rear directions were appeared when the stereogram was pierced optical system and affected magnification by lenses and it is a critical problem to recognize right depth to an observer compared to case in non-optical system. Since the existing stereogram as input image usually involve disparity for the real object used by stereo camera and it provides 3D depth to an observer but which is optimized to the flat panel 3D display based on non-lens system. The size of stereogram as well as quantify of disparity have to be equal magnification after through the optical system however depth cues can not present right depth to an observer despite cases of them. The reason why depths are distorted is that viewing and base distances were not taken effect by magnification of lenses, in other word, they keep going to initial values such as in non-optical system. To compensate distorted depth, we proposed the method to take 3D image having correct ratio of depth to the front and rear directions in optical system that is controlling disparity in stereogram which was considered by total magnification of optical system, viewing distance and base distance of viewer.

Although several studies have been made on this problem but it only corresponded to point of view in non-optical system, there is little investigation in optical system. In this article, we will introduce our investigation to compensate depth using the controlled disparity in stereogram with AFIS. This is composed by the floating image system (FIS) and the stereoscopic vision system (SVS). Firstly, the FIS has a primary role to provide pseudo 3D depth which leaded to input source as image or object to an observer by optical system then input source was displayed on the space between the display and an observer. Secondly, the SVS has a role to present front / rear depth cues due to the disparity in the stereogram. In this system, SVS was applied compensated disparity to present right depths by our method.

We investigated the AFIS to compensate distorted depths using the relation of the viewing distance, the base distance and the magnified disparity by lenses as well as to provide correct front / rear depth cue to an observer, consequently. It was performed by based on qualitative and quantitative analysis. In experiment, the AFIS is composed by triple planar-convex fresnel lenses and a polarized glasses type stereoscopic display was applied to embody stereoscopic vision.

Furthermore, The AFIS has a capability to presents selectively 2D and 3D by user, thus it will be used widely applications such as in education, culture, entertainment, science and medical field and so on. Figure 1,2 shows that scheme and configuration of the AFIS.

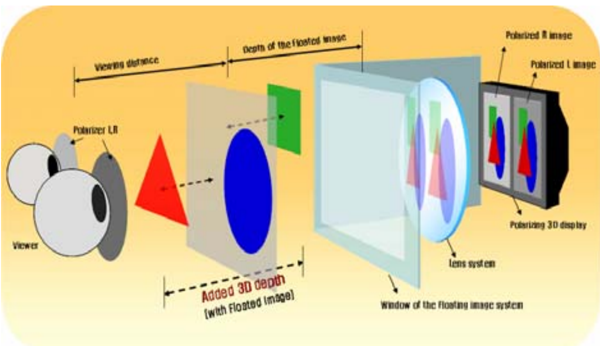

Fig. 1. Scheme of the AFIS

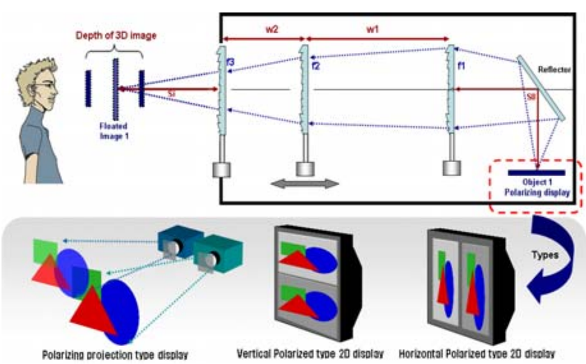

Fig. 2. Configuration of the AFIS

2. Theory and Experiment

As a discussed to the cause of critical problem in introduction, the distorted depth is caused by demagnified disparity which is not equal to magnification of total lenses in AFIS. To remove depth distortion related between total optical power and displayed disparity in stereogram, we have to make an exclusive stereogram which was applied compensated disparity. Equation (1)-a,b presents calculated quantifies of disparity and depth related to total optical power for the front or rear directions at displayed image plane, in here M_{Tk}, P, A and B are transverse magnification to the number of lenses(k), the value of front directional disparity in stereogram of non-optical system and the value of front directional disparity in stereogram of optical system. A_k presents equal to B also. The variables with marked prime right upper side present case of the rear direction. Equation (2)-a,b presents each depth ratio in cases of front and rear directions between non-optical system and the other. Therefore, we can drive the significant values for compensating depths are compensated disparity from Equation (1), (2). The theoretical results of the several cases for compensating depths are presented. Fig. 3. show the qualitative results to the front and rear depths from relation of disparities in stereogram by magnification of optical power compared with non-optical system.

$$\begin{cases} P_k = M_{Tk}\,P \\ A_k = B = \dfrac{P_k(VD)}{(BD+P_k)} \end{cases} \quad (1)\text{ - a}$$

$$\begin{cases} P_k' = M_{Tk}\,P' \\ A_k' = B' = \dfrac{P_k'(VD)}{(BD-P_k')} \end{cases} \quad (1)\text{ - b}$$

$$\frac{B}{A} = \frac{M_{Tk}(BD+P)}{(BD+M_{Tk}\,P)} \quad (2) - \text{a}$$

$$\frac{B'}{A'} = \frac{M_{Tk}(BD-P')}{(BD+M_{Tk}\,P')} \quad (2)\text{ - b}$$

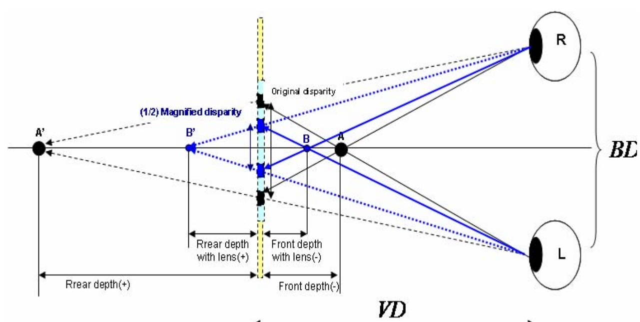

Fig. 3. Configuration of the AFIS

The output stereogram through the AFIS that has the floated depth was 226mm from the last fresnel lens and has the 0.44 magnification comparing to the size of input image. The used constraints are following that the size of input image, the focal lengths of lenses, the spaces of lenses, VD, BD and the distance of object are 17", 700mm(1st), 400mm(2nd), 700mm(3rd), 400mm(1st to 2nd), 100mm(2nd to 3rd), 800mm, 65mm and 608mm. Fig. 4 show the real experimental set up to the AFIS

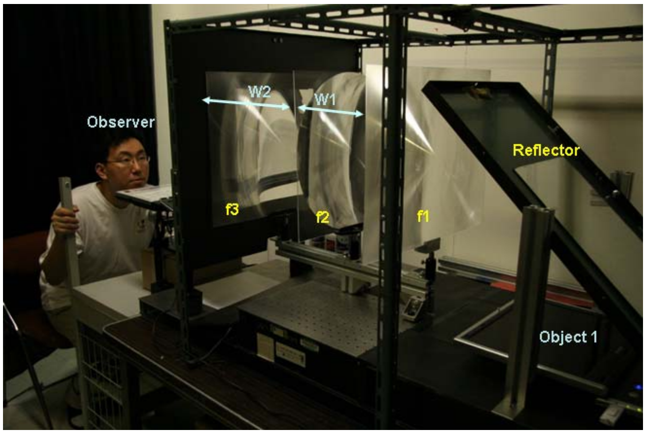

Fig. 4. Real experimental setup to the AFIS

3. Results and discussion

As a result, the distorted depth cues were compensated by series of calculated disparities for providing accurate depths to an observer in AFIS. Fig. 5–(a),(b),(c),(d). shows the results which are considered to the relations of the viewing distance (VD), the eyes distance (BD) and the compensated disparity in stereogram and Fig. 6. show the displayed object shape for the each cases of ordered compensating with numerical disparities which was compared to initial disparity has 20 pixels, here, disparity has unit number of pixels and if we want to take detail information to the disparity as length, just magnifying unit pixel size to output. To verify compensating depth, as follows steps are used. Firstly, input the equal disparity to the front and rear directions as P=P' at initial stereogram then extract value of the depths A and A'. Secondly, let disparity P standard, calculate the compensated disparity P'_c to make A=A'. Thirdly, as same way to the first step for taking P'_{lc} but it was performed by point of view rear direction in order to B=B'. Finally, we taken having the perfectly compensated depth ratio cases in both optical system and non-optical system as P'_r. The theoretical results of the several cases for compensating depths are presented by Table 1. and please refer to Fig. 5-(a),(b),(c),(d).

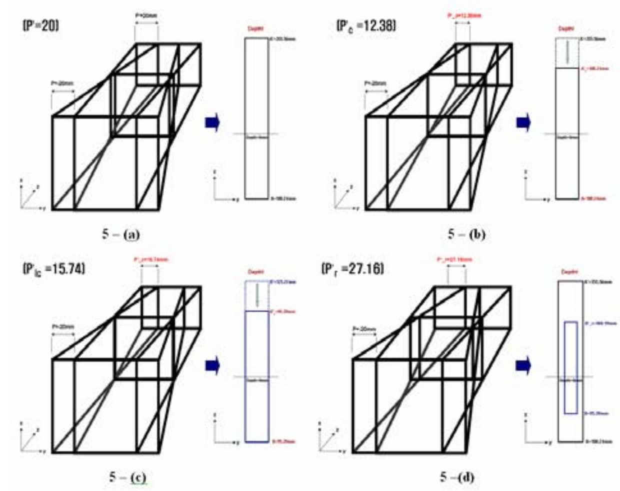

Fig. 5. Simulated results for compensating depths

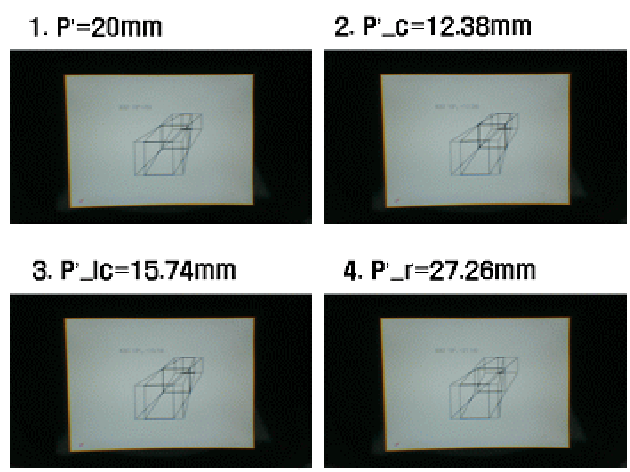

Fig. 6. Experiment results for compensating depths with AFIS

Table 1. Relation of compensated disparities

Meaning	Front disparity	Rear disparity	A = A'	B = B'	A'/A = B'/B
Disparity	P	P'	P'_c	P'_{lc}	P'_r
Relations (Std; P)	$\frac{A(BD)}{(A-VD)}$	$\frac{A'(BD)}{(A'+VD)}$	$\frac{P(BD)}{(2P-BD)}$	$\frac{P(BD)}{(2M_T P-BD)}$	$\frac{A' B\,(BD)}{M_T(VD\,A+A'B)}$
Disparity	P	P'	P_c	P_{lc}	P_r
Relations (Std; P')	$\frac{A(BD)}{(A-VD)}$	$\frac{A'(BD)}{(A'+VD)}$	$\frac{-P'(BD)}{(BD-2P')}$	$\frac{-P'(BD)}{(BD-2M_T P')}$	$\frac{-A\,B'(BD)}{M_T(VD\,A'-A\,B')}$

4. Conslusion

The AFIS have two advantages one is possible to provide the accurate depth to an observer by compensated disparity and the other is available to interact the rear depth with pseudo 3D depth on the displayed image comparing with an existing flat panel 3D display. The AFIS to be applied widely to embody real 3D depth and it to be utilized medical or entertainment fields and so on.

5. References

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