Advanced Secure Display Using DFD Display with Fuzzy Perceived Depth Images and Dummy Information

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Keywords: Security DFD Display, Combining Random Dot Configuration, Fuzzy Luminance Distribution

ABSTRACT

We propose a high-security display that prevents peeping even with computer analysis by using the DFD display with fuzzy depth or color and brain complement. Our high-security display can successfully provide information only to human but prevent recognizing by peeping or camera capture with computer analysis.

1 Introduction

Today, as multiple displays are usual for a person, such as cell phones and computers, protecting personal information on displays is an important issue. In particular, security against peeping even with computer analysis is more important at cash point, etc.

One of the conventional securities for displays is the louver film to prevent peeping eyes. However, as louver film [1] has a rather wide viewing angle, information can be peeped even from a slight angle, it is also recognized by photograph taken from around front position, not just from the front.

Secure displays that provide information only to humans from a specific viewpoint but no information to camera nor computer could ensure a high level security against peeping even with computer analysis. We propose for secure display to use DFD (Depth-fused 3D) display with adequate narrow viewing zone of perceiving depth and brain complementation for fuzzy conditions, such as depth, color, angle, and etc.

Figure 1 shows principle of DFD display [2][3]. The DFD display is a 3D display method in which the overlapping portions of the front and rear images can be perceived as a single image with depth, and the depth position of the image can be changed continuously by adjusting the luminance ratio of the front and rear images. DFD display is suitable for security against peeping eyes because it requires superimposition of front and rear images within narrow interocular distance and DFD image depth can be intuitively recognized only by the human. For example, although computer can analyze the depth information if superimposed angle and its parts are known, only human easily recognize the information even if he/she does not know superimposed angle and its parts.

Moreover, for difficulty in computer analysis of the information, we adopt brain complementation for fuzzy conditions, such as depth, color, angle, etc. For example, although computer can also analyze the information if fuzzy conditions are known, only human easily and intuitively recognize the information even if he/she does not know which fuzzy conditions are used.

In this paper, we propose to combine DFD display with brain complementation in fuzzy depth, color angle, etc. for realizing high secure display against peeping with computer analysis. Our secure display provides information only to humans, and prevents recognition by camera nor computer analysis.

In our secure display using DFD display and brain complementation, fake information (dummy information) can be easily displayed to increase security level at different viewing angles, where the correct information is perceived from different angles. Uchida et al. reported dummy information method using polarization calculation by stacking three liquid crystal panels to enable switching between three viewpoints and a secure two-viewpoint display that prevents peeping eyes [4]. This requires as several LCD panels to display the same number of dummy information, because their purpose is to provide full resolution images. However, as our purposed method is to confuse peeping people which information is right or not, DFD display easily provides dummy informations by changing superimposed angles without changing the number of displays.

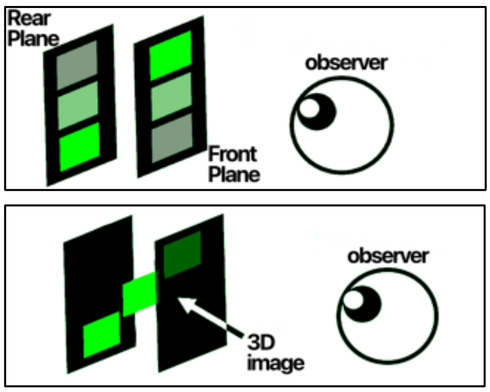


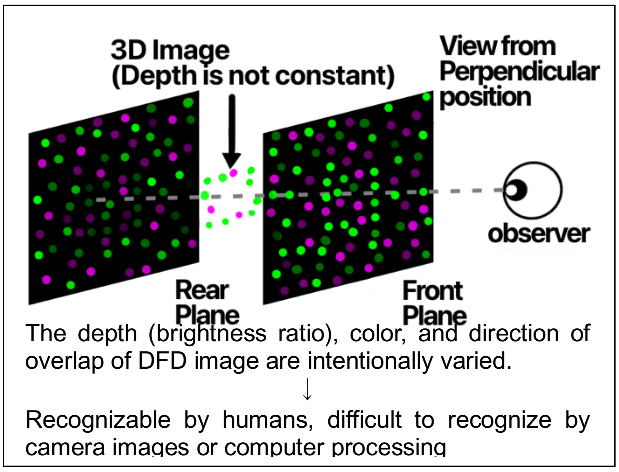
Fig. 1 Principle diagram of DFD display

2 Principle of high security displays using the proposed DFD display method

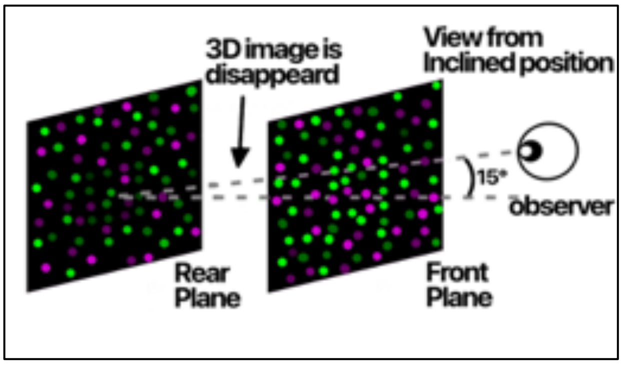
Figure 2 illustrates the principle of our proposed high security display. Figure 2(a) shows viewing images from intended angle perpendicular to the plane (0°). As composed dots of hidden information (square) overlap, perceived depths of the dots are different from other regions and hidden information of square can be recognized. On the other hand, in Fig. 2(b) viewed from undersigned diagonal angle of ±15°, composed dots of hidden information do not overlap and the hidden information cannot be recognized. Figure 2(c) shows the image viewed from designed diagonal angle of +10° for dummy information. Composed dots of dummy information (triangle) overlap, and perceived depth difference in dummy information provides information recognition. Thus, overlapped condition of depth perception in DFD display can achieve simple secure display.

In addition to simple secure display using DFD display, utilize of brain complementation can improve our secure display to higher level. For example, although random change of various parameters (luminance ratio, color, angle, etc.) make it difficult to analyze information by computer, human brain easily and institutionally recognizes the information even with fuzzy various parameters. In Figs. 2(a) and 2(c), the fuzzy arrangement of the dot colors and luminance ratios in the front and rear images makes it difficult to derive the hidden information by computer. Although this fuzzy arrangement of luminance ratio leads to different perceived depth, human brain easily recognizes the information. In Fig. 2(b), as the dots other than the hidden and dummy information are random dots, the target dot blends in with the surrounding dots when viewed from other than the front.

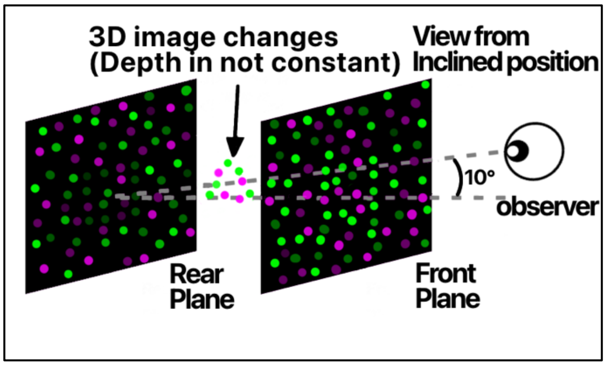
Moreover, in Fig. 2(c), addition of the dummy information dots and dense arrangement for easy recognition at designed diagonal angle of +10°, make it easier to recognize and to mistake.



(a)When viewed from perpendicular position to planes
(0 degrees)
(Intended information)



(b) When viewed from undersigned diagonally right angle (15 degrees)
(Can't see the information)

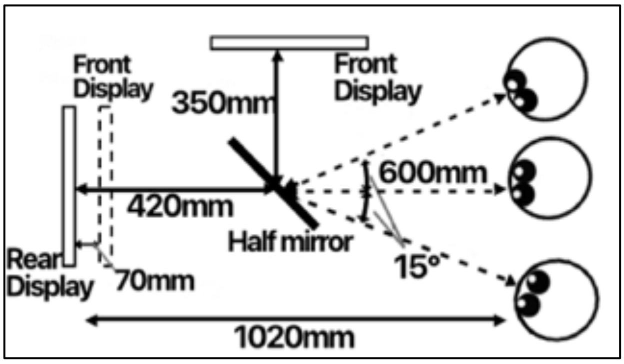


(c) When viewed from designed diagonally right angle (10 degrees)
(Dummy information)

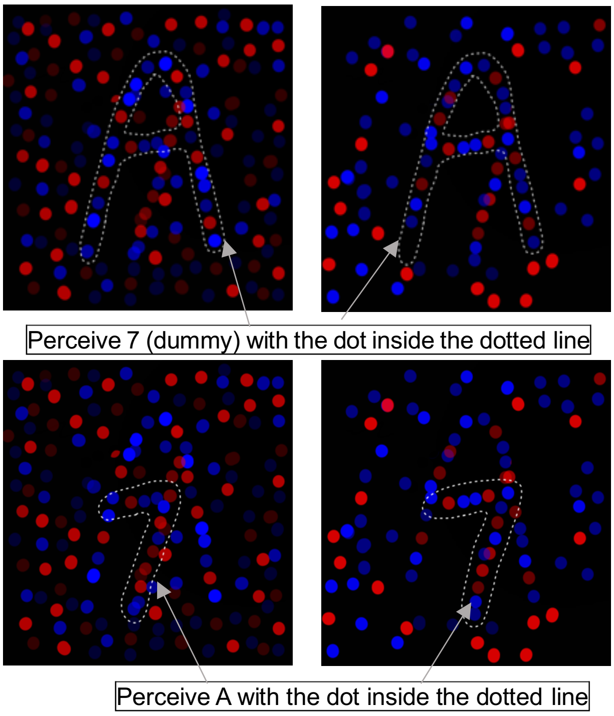
Fig. 2 Principle of our proposed secure display

3 Experiments on high-security displays using the proposed DFD display method

Figure 3 shows (a) experimental system, (b) front image and (c) rear image of intended hidden information and dummy information. The experimental system consisted of two displays and a half mirror. The distance from the observer to the half mirror was 600 mm, the distance to the front display was 350 mm, the distance to the rear display was 420 mm, and the distance between the front and rear displays was 70 mm. Random dots were used so that the composed dots of hidden information "4" overlap only from the perpendicular position to the front and rear planes (0 degrees). Composed dots of dummy information "7" are overlapped from diagonal direction of 10 degrees.



(a) Experimental equipment



(b)Front image (c) Rear image

Fig. 3 Experimental system of half mirror DFD

Apart from composed dots of intended hidden information and dummy information, random dots were arranged to be overlapped or not to be, overlapped in a random way for increasing security.

The luminance ratios between the front and rear images for the composed dots pair of intended hidden information and dummy information were set from 4 : 6 to 6 : 4. Luminance ratios of the other randomly arranged parts was set from 1 : 9 to 9 : 1. The dot colors were also randomly set.

Composed dots of dummy information "7" were densely positioned for easy recognition even by photograph. Whether the depth can be perceived and the figure can be recognized only in the part of the figure to be displayed were evaluated. Whether or not the figure to be displayed could be recognized when the overlapping state was photographed with a camera were also evaluated.

4 Evaluation Results on Proposed High Security Displays

The evaluation results for two subjects with viewing angles of 0°, +10°, +15°, and -15° are shown in Table 1. When viewed from an angle of 0°, the hidden information "4" contained in the random dot can be recognized with fuzzy depth perception. However, when observed from 15° and -15°, the hidden information "4" is confused with the surrounding dots, and neither subject can get the hidden information. The dummy image (7) can only be recognized at a viewing angle of 10°. Even at a viewing angle of 10°, the hidden information "4" was confused with the surrounding dots and the hidden information could not be recognized. Viewing angle for secure display is related to the distance between the front and rear planes (70 mm). The longer the distance between the planes, the narrower the viewing angle where the dots overlap. However, the wider the distance between the planes, the harder it is for an observer looking from the front to recognize hidden information, so 70 mm was selected for this test.

Table. 1 Evaluation results

	Observer's viewing angle				Image taken with camera
	-15°	0°	10°	15°	
Observer A	×	○	□	×	×
Observer B	×	○	□	×	×

Can be perceived (○) Perceive a dummy (□) Cannot be perceived (×)

Fig. 4, 5, 6, 7 shows photographs of display that can be seen when dots are arranged on the front and rear surfaces, 0° is the front surface, and observations are made in the ranges of + 10°, + 15°, and -15°.

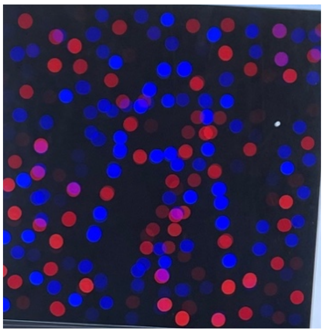
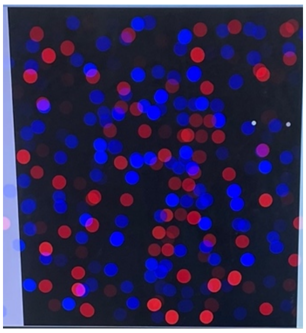


Fig.4 When viewed from 0°

When viewed from the front (0°) (Fig.4), the camera does not show the DFD display as shown in Fig. 2(a), but by adjusting the position and luminance ratio of the overlapping dots, only the figure to be displayed can be seen by the human as the DFD display.



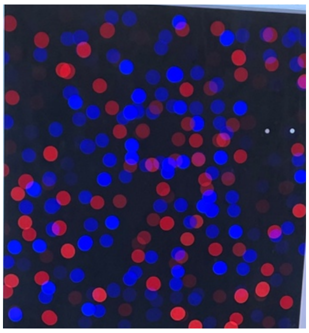


Fig.5 When viewed from +15°

Fig.6 When viewed from -15°

When viewed from + 15° and -15° (Figs. 5 and 6), the information intended to be displayed is mixed with the surrounding random dots, making it impossible to perceive the figure and depth.

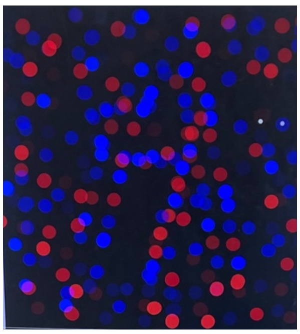


Fig.7 When viewed from +10°

When viewed from +10 (Fig.7), the figure intended to be displayed is mixed with the surrounding random dots, and the figure and depth can not be perceived. In addition, the dummy figure "7" can be perceived as shown in Fig. 3(d).

As the luminance ratio of the dots front and rear the hidden and dummy information is not constant, ranging from 4:6 to 6:4, and varies slightly in depth, the information cannot be recognized by computer analysis of the images before and after.

5 Conclusions

We proposed a new high-security display method to prevent peeping using depth perception by DFD display, and evaluated the possibility of recognizing figures in observations from different angles and captured images.

By randomly arranging the colors and brightness of the random dots, the target information cannot be recognized in camera photography, and by separating the faces, the target information can only be seen from the front, and dummy information are also effective.

Thus, we proposed a new method to introduce randomness of color, luminance ratio and depth into DFD display, and clarified that security can be improved.

Acknowledgment

This research was supported by JSPS Grant-in-Aid for Scientific Research, 19H04155, 20K11919, 20K21817, 20H05702.

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