Moirés in 3-D Display: How to eliminate them

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Abstract

Moirés are a natural interference phenomenon which occurs whenever a transparent regular pattern plate is overlapped on another regular pattern plate. In the contact-type 3 dimensional imaging systems, the moirés are inherent because an image display panel is seen through a viewing zone forming optical plate. The mathematical analysis of moirés in the systems shows that they can be minimized by the proper selection of overlapping angles between them. The angle is different for pixels with different aspect ratios. (2 line spacing)

1. Introduction

When two transparent regular pattern plates are overlapped together as in the contact-type 3 dimensional (3-D) imaging systems, moirés are inevitable. The presence of moirés in the 3-D imaging systems due to overlap of a viewing zone forming optics on the flat panel display panel, is reducing greatly the visual quality of the 3-D image perceived by viewers. The moirés are periodic patterns appearing across the display panel/ the optics. They are viewed as a periodic color strip array and enhanced when the image has a white background. It is known that the moirés are created by a beating process of two regular pattern plates with different pitches. However, the misalignment also contributes greatly to the moirés appearing on the systems. Since in the 3-D imaging systems, the pitch of the viewing zone forming optics is designed to be slightly smaller than that of the display panel [1], the moirés are inherent to the 3-D imaging system. This means that the moirés cannot be completely eliminated. Added on this difference, if the misalignment is also done, the moirés will be greatly enhanced. Furthermore, the relative pitch ratio between the optics and the panel is changing as the viewers change their viewing positions. As a consequence, viewers perceive moirés with different frequencies as they change their positions. This makes the moiré more visible. The moirés can be reduced by partially breaking the regularity between the panel and the optics but this will not be a desirable way because it will not be realized with a cost. The cost will be reductions in image resolution and brightness [2]. Hence no depth sense can be obtained. Another way is keeping the regularity but minimizing the moirés by finding a proper superposing angle between them [3]. This is the more feasible way of realizing because the moirés can be made unrecognizable by making their periods smaller than the length which viewers' eyes can resolve. When two regular pattern plates are superposed, there appear 41 different moirés with different periods [4]. When they are properly laid, the resulted moirés are made in the outside of the value range which can be resolved by viewers' eyes, though their intensities are not the same. Furthermore, these resulted moirés are indifferent to the viewers' position changes because the 41 different moirés are covering the moirés from the position changes.

In this paper, the moiré reduction method in contact-type 3-D imaging systems is reviewed.

2. Examples of moirés

In the contact-type 3-D imaging systems, the display panel is typically consisted of a square pixel array as shown in Fig. 1(a). The two dimensional viewing zone forming optics are also having the same structure as the display panel but some cases they have a rhomb pattern as shown in Fig. 1(b) [5].

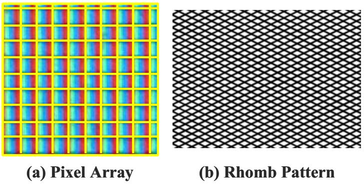
(a) Pixel Array (b) Rhomb Pattern

Fig. 1. Pixel pattern on the display panel(a) and elemental optic array of the viewing zone forming optics(b).

The typical moirés appearing when two transparent plates with the same strip pattern are overlapped is shown in Fig. 2. When two plates are completely aligned, no moiré is appearing but they are slightly misaligned, the moiré is created. The moiré period becomes wider as the alignment completes.

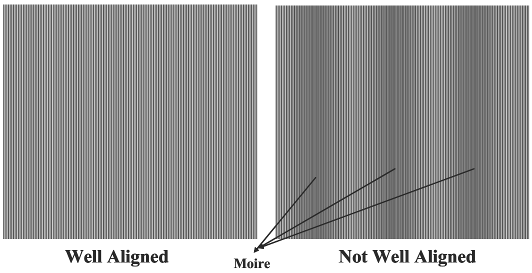

Fig. 2. A typical moiré when two transparent plates with the same strip pattern are not well aligned.

In the practical situation, the images are appearing as if they are painted with certain colors and the colors become slightly different as the viewers change their viewing direction when moirés are present. Fig. 3 shows the color burred images on a 3-D imaging system due to overlap of a viewing zone forming optics as shown in Fig. 1(b) on the panel with the pixel array as shown in Fig. 1(a).

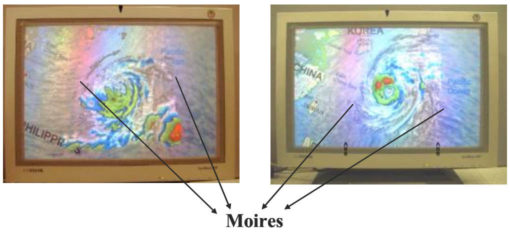

Fig. 3. Moirés appearing on the 3-D display panel with a viewing zone forming optics with a rhombic pattern.

As shown in Fig. 3, it is obvious that the moirés deteriorate the visual quality of the image tremendously. Hence these moirés should be removed to enhance the visual quality of the image.

3. How to reduce moirés?

In the contact-type 3-D imaging systems, lenticular and parallax barrier plates are mostly used as the viewing zone forming optics[6]. The alignment pattern of elemental optics in these plates can be represented as a line grid. The pixel alignment in the flat panel displays has the form of a two-dimensional line grid. When it is assumed that the plates also have a two-dimensional line grid pattern for full parallax image display, superposing two two-dimensional line grid patterns with a certain angle produces moirés with 41 different periods though their amplitudes are not all the same. Among these 41 different moirés, some of them are directed to the direction defined by the relationships defined by the angle and the pitch ratio of the two grid patterns, and another some the direction near normal to the former direction and remains directed to both directions. It turns that these 41 moirés have periods close to each other for most of the angle ranges so that when these moirés are overlapped together, the resulted moiré is having a distinctive period. However, the angles close to a certain angle, the moirés are filling the gap defined by the distinctive moiré period. This is shown in Figs. 4 and 5. Fig. 4 is theoretically calculated moirés for several different angles for each of several pitch differences between the viewing zone forming optics and the display panel. Each picture in Fig. 4 clearly shows that the moirés are directed to two different directions and the directions are near normal to each other. Fig. 4 shows that as the angle nears to 26°, the period of moiré becomes smaller and its variation for different values of the pitch difference becomes less distinctive. For angles 0° and 45°, the moirés are very distinctive and their periods become smaller as the pitch difference increases. These period changes make the moirés more visible because the relative period changes due to viewers' head shifts induces different period moirés. Furthermore, for angles 0° and 45°, no moiré (45°) or invisible moiré (0°) due to viewers' eye resolution limit, condition can be obtained. However, the small shifts in viewers' eye position changes can cause the no moiré and the invisible moiré conditions to moiré causing condition. The some magnified images of Fig. 4 are shown in Fig. 5. These images show that is the moiré density is higher for 26° than 22°, especially, when pitch difference is 8%. For the case of 22°, the moiré density keeps the same but for the 26°, the density becomes higher for larger pitch differences. This means that the gap between the higher period moirés are filled by lower period moirés without overlapping to others as the angle nears the 26° and the pitch difference becomes increases. As the density becomes higher, the resulted moirés are more uniformly distributed and their fringe periods become small enough to be unresolved by the viewers eyes at a given viewing distance. Since the moirés are symmetric along 45° line, as the angles close to 26° or 64°, the moirés becomes less visible. The superposing angle which results the highest density moirés are found from the moirés terms which are giving highest moirés periods. Since the moirés are directed to two different directions, each direction has its highest period moiré. Hence the angle can be found from these two highest moiré period terms. It is expected that remain 39 terms will fill the gap between the moirés defined by the two highest period moirés.

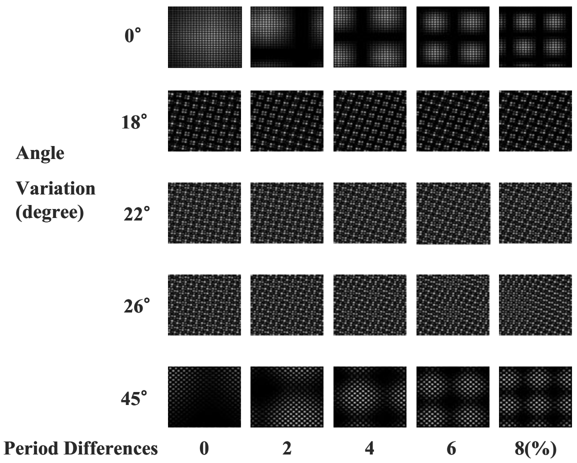

Fig. 4. Moire variations for several different overlapping angles and period differences between the plates.

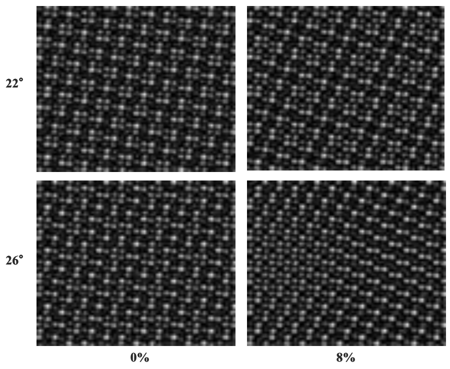

Fig. 5. Magnified image of Fig. 4.

4. The angle for the highest density moirés

The highest moiré period terms for the two directions are given as [4],

$$\begin{aligned} f_1(\rho,\alpha) &= \sigma^2 + \rho^2 - 2\sigma\rho\cos\alpha - 2\rho\sin\alpha + 1 \\ f_2(\rho,\alpha) &= \sigma^2 + \rho^2 - 2\sigma\rho\cos\alpha \end{aligned} \qquad (1)$$

In Eq. 1, f_1 and f_2 represent moiré periods for two different directions, α , ρ and σ the superposing angle, pitch ratio of the viewing zone forming optics to the pixel and the aspect ratio of a pixel in the display panel, respectively. Hence ρ cannot be smaller than 1. σ is 1 for square pixels and ≥ 1 for rectangular shape pixels. To find the angle for the highest density moirés, the values α and ρ which are maximizing f_1 and f_2 for a given σ value should be found. The α and ρ values will be found by differentiating the f_1 and f_2 by α and ρ . This differentiating gives,

$$\begin{aligned} &\rho_1 = \sigma\cos\alpha + \sin\alpha \quad \textit{and} \quad \tan\alpha_1 = \frac{1}{\sigma} \\ &\rho_2 = \sigma\cos\alpha \quad \textit{and} \quad \sin\alpha_2 = 0 \end{aligned} \qquad (2)$$

ρ_1 and α_1 , and ρ_2 and α_2 are extreme values for f_1 and f_2 respectively. Eq. 2 indicates that $\sigma\cos\alpha + \sin\alpha$ is always greater than 1 for $\tan\alpha = 1/\sigma$ so that $\rho_{1\max} = \sigma\cos\alpha + \sin\alpha$, however, $\rho_{2\max}$ should be σ because $\sigma\cos\alpha$ can be less than 0 when $\alpha_2 = 0$. Since the superposing angle which produces the highest period moiré should be equally applied for two different directions, for these $\rho_{1\max}$ and $\rho_{2\max}$ values, f_1 and f_2 should have the same value. This condition results as,

$$\sigma^2(1 - 2\cos\alpha) = (1 - \sigma^2)\cos^2\alpha - 2\sigma\cos\alpha\sin\alpha \qquad (3)$$

Eq. 3 calculates that α is 26.2609°, 13.9858° and 9.4465° for σ values of 1.0, 2.0 and 3.0, respectively. These α values create the highest density moirés for the given σ values. Fig. 6 shows the moirés appearing on the white background of a 3-D image display panel for three different α angles. It can be seen that the moirés are diminishing as the angles are close to the 26° and almost no moirés are seen for α =26.2609°.

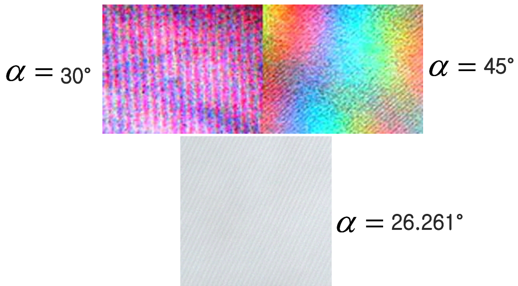

Fig. 6. Comparisons of moirés appearing 3-D display panel for three different angles.

Fig. 7 shows the same image shown in Fig. 3, displayed on the 3-D display panel which is constructed by superposing a 2 dimensional lenticular plate(two lenticular plates are superposed with the 90° crossing angle) to keep on the top of a LCD display panel with α = 26.57°. Since the angle 26.2609° can be hardly adjusted, the angle is approximated by 26.57° which corresponds to the slope of 2 pixels in horizontal direction and 1 pixel in vertical direction. Fig. 7 clearly shows that there are not any visible moirés even at the white background. Comparing with Fig. 3, the visible image quality is greatly improved. This means that the angle 26.2609° is really effective in minimizing the moirés for square pixel type display panel. For the display panels with a rectangular shape (2:1 aspect ratio) pixel array, the angle 13.9858° will be effective.

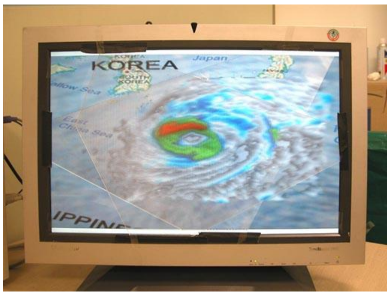

Fig. 7. 3-D image with no moirés.

5. Summary

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Moirés are inherent to contact-type 3 dimensional imaging system. The moirés cannot be eliminated but they can be made invisible by adjusting the superposing angle of the viewing zone forming optics on a flat display panel. When the panel is consisted of a square pixel array, the angle 26.57° is effective in making the moirés invisible. For the panels consisted of 2:1 aspect ratio pixels, the effective angle will be 14°.

(2 line spacing)

5. References

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