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Pseudo 480-Hz Driving Method for Digital Mode Grayscale Displays

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Abstract – A pseudo 480-Hz drive method has been proposed to reduce the dynamic false contour noise that occurs on flat panel displays with displaying grayscale image in the digital mode, such as plasma display panels. The proposed method makes the image movements nearly continuous by rearranging the 8-bit image data displayed for 1 TV field into 8 subfields. The position of the image data rearranged in subfields has been optimized on the basis of the speed of the moving image by computer simulations for the dynamic false contour noise. It is verified that a significant reduction in the dynamic false contour noise is achieved with the proposed method as compared to the conventional noise reduction technologies. Moreover, to reduce the noise in digital mode displays, the proposed technology requires only 8 subfields. Therefore, there is no reduction in the brightness of the image.

Keywords: Computer simulation, Dynamic false contour noise, Digital mode grayscale display, Flat panel display

1. Introduction

Unlike cathode ray tubes (CRTs), flat panel displays (FPDs) are hold-type displays in which the pixels are kept ON for a certain duration. Further, in hold-type displays, an image moves discontinuously along the pixels, while the human eyes catching up with this image move continuously. As a result, human eyes observe various virtual noises in the moving images. Liquid crystal displays (LCDs) are analog displays that present grayscale images by controlling the amount of light passing through a liquid crystal. In the case of LCDs, motion blurs are produced, i.e., the outline of a moving image becomes blurred [1, 2]. On the other hand, it is called as digital mode displays that the displays represent grayscales on the basis of the length of time required to hold light emissions in a 1TV field, such as plasma display panels (PDPs). The duration for which the image is displayed is always shorter than 1TV field in the digital mode display; as a result, motion blur in PDP is less than that in LCDs.

However, the digital mode displays suffer more significantly from dynamic false contour (DFC) noise in which a virtual contour is observed on the boundary line between the two gray levels of moving images [3, 4]. Because the DFC noise is dependent on the actual moving distance of the image on the screen, the larger the screen size, the more noticeable is the noise. In addition to PDPs, Digital Light Processing© (DLP) projectors that use digital micro-mirror devices (DMDs) are also often used to display grayscale images in digital modes. Further, digital broadcasting can be expected to completely replace analog television broadcasting in a few years. Therefore, digital methods will become highly preferred for presenting grayscale images, especially for use in image signal processing systems. Digital gray scaling is expected to become a common display technique for future FPDs including those using organic light-emitting diodes (OLEDs) that are considered as promising candidates for next-generation displays. Therefore, the development of DFC noise reduction technology is imperative for large-screen FPDs that use digital methods for displaying grayscale images.

With the increasing commercialization of PDPs, many investigations have been conducted to achieve DFC noise reduction in the digital mode displays, and several methods have been elucidated. The 1TV field in the digital mode displays is divided into 8 subfields (SFs) that correspond to each bit length to represent the images of 8-bit 256 gray levels, as shown in Fig. 1(a) [5]. The typical methods used to reduce the DFC noise is to split the SF corresponding to the largest bit into multiple SFs with smaller bits (Fig. 1(b)). In addition, the DFC noise can be dispersed by inserting the divided SFs between other SFs, as shown in Fig. 1(c) [6]. As stated above, when the number of SFs is increased to reduce the DFC noise, the image quality does not deteriorate, because there are no grayscale losses. However, the brightness of image decreases because the time available for the light emissions relatively decreases.

Another method of reducing the DFC noise is to insert an equalizing pulse into the gray level signal in which the noise occurs in order to compensate for this noise [7]. A method for rearranging the image data displayed on SFs on the basis of the movements of images by detecting the motion vectors of images has also been reported [8]. In commercialized PDPs, two modes – a high-quality, low-brightness mode with increased number of SFs to reduce

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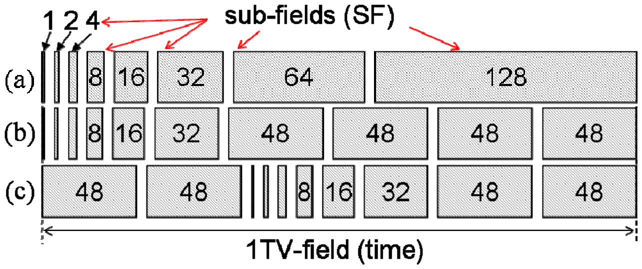

Fig. 1. Structure of 1TV field in digital mode displays: (a) Simple field structure of 8-bit 8SFs; (b) Divided MSB structure of 8-bit 10SFs; (c) Divided MSB and location shift structure of 8-bit 10SFs

DFC noise, and a low-quality, high-brightness mode with the same number of SFs but some of which are used to reduce noise – have been employed together. Although the low-quality, high-brightness mode does not decrease the brightness, it reduces the number of gray levels that can be displayed. Therefore, these losses are compensated for by error diffusion or dithering [9-11]. Meanwhile, the high-speed driving of digital mode displays at 120 Hz is effective in reducing the DFC noise because of the reduction in the time required for displaying a 1TV field [12].

In this paper, a new pseudo 480-Hz drive technology is proposed for digital mode displays. This technology has an optimized arrangement of the data for SFs in accordance with the speed of the moving image. Moreover, the proposed technology makes it possible to reduce the DFC noise and represent 8-bit grayscale images using only 8 SFs without causing any decrease in either quality or brightness of image. The feasibility of the proposed technology has also been verified in this work by using computer simulations.

2. Dynamic False Contour Noise Recognition Model

The brightness values of most FPDs are divided into 256 gray levels of 8 bits from 0 to 255. Further, as shown in Fig. 1(a), a 1TV field is divided into 8 SFs that correspond to each bit length to represent the grayscales of 8-bit 256 gray levels in the digital mode displays. In the 8 SFs, light emission is maintained for time lengths of 1/256, 2/256, 4/256, 8/256, 16/256, 32/256, 64/256, and 128/256, respectively. The light emissions of these SFs are selectively controlled to display grayscale images. For example, to display an image with the 127th gray level, the SFs with light emission times of 1/256, 2/256, 4/256, 8/256, 16/256, 32/256, and 64/256 are turned on sequentially. On the other hand, for displaying an image with the 128th level, only the SF with emission times of 128/256 is turned on.

DFC noise often occurs in digital mode displays because the human eye does not perceive moving images in the exact way in which it moves on the screen. When a human eye sees moving images, the sight line is presumed to perfectly track the moving image to locate the images on the center of the retina. Moreover, it is also assumed that optical stimulations within 1/60 s are perceived in an average value only after being perfectly integrated in the visual system [1, 2, 13]. Then, the DFC noise can be explained by the model shown in Fig. 2 [3, 4]. Fig. 2(a) is a conceptual diagram in which the images with the 127th and 128th gray levels are adjacent to each other, and the border between the two images moves from left to right at the rate of 1 pixel/field. Here, the rectangle represents a pixel of the image. The horizontal axis indicates the horizontal position of the pixels on the screen, whereas the vertical axis refers to the time used to maintain the emissions in the 1TV field. The images move discontinuously from left to right in a row along the pixels, while the eyes of the viewer move continuously tracking this image. As a result, the pixel is perceived as a parallelogrammic shape on the retina, as shown in Fig. 2(b). Therefore, a white bright virtual contour is observed along the border between the 127th and 128th gray levels.

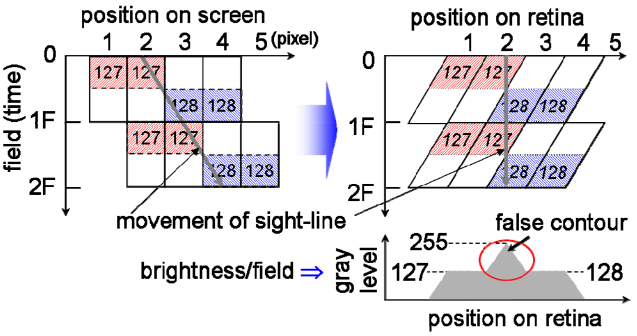

Fig. 2. DFC noise recognition model. (moving image) Conceptual diagram of (a) moving image on the screen and (b) image shape perceived on the retina

The reason that DFC noise occurs can also be explained as follows: After the image moves as shown in Fig. 2(a), the gray level of pixel 3 changes from 128 to 127 in the next field. The 128th gray level implies that the SF occupying the latter half of the 1TV field has lit up, whereas the 127th level implies that the SFs occupying the first half of the 1TV field are all lit. Therefore, when the gray level of the pixel is changed from 128 to 127 in the next field, the 128th and 127th levels are perceived consecutively. As a result, the bright part with the 255th gray level is recognized. On the other hand, when the gray level of the pixel is changed from 127 to 128, a dark part with the 0th gray level is perceived. The DFC noise is perceived only when the viewer's eyes trace the image on the digital mode displays, and it is not recognized when they do not trace the image.

3. Principle of Pseudo 480-Hz Driving Method for Digital Mode Displays

The movement of an image on the FPD is discontinuous, whereas the movements of a viewer's eyes are continuous. As a result, virtual noise occurs in the moving image, and this noise can be reduced by making the movement of the image continuous. To reduce the blur noise, 120-Hz and 240-Hz drive technologies are used in LCDs [1, 2]. This method makes the movement of image continuous by inserting a newly generated field between two original fields. However, in the case of digital mode displays, because the time required to maintain light emissions are separated for each SF, it is difficult to apply such high speed driving technology that employ the insertion of a new field. Nevertheless, it is possible to make the image movement continuous by using SFs in digital mode display.

Fig. 3 shows the application of the proposed method to a digital mode display that has 8 SFs to display 8-bit 256 gray scales. Fig. 3 shows an application to an image with the border between the 127th and 128th gray levels moving from left to right at the rate of 5pixels/field. As shown in Fig. 3(a), it is assumed that image A moves to image B in the next field at the speed of 5pixels/field on the screen. By using SFs in the current field, five virtual image data are created between image A in the current field and image B in the next field. Fig. 3(b) shows the bit data arrangement of the image assigned to the 8SFs with displaying 8-bit 256 gray scales; here, the proposed technology is applied to a digital mode display. When the border between the two images with the 127th and 128th gray levels moves from left to right, the bit data of the image are rearranged on the SFs composing the 1TV field in order for the movement of the image to approximate continuous movement, as shown in Fig. 3(b). The 1st~4th-bit data are displayed on SF1~SF4 in the pixel of the original position respectively, and the 5th- and 6th-bit data are respectively displayed on SF5 and SF6 in the 2nd pixel of the next position. The 7th-bit data is displayed on SF7 in the 3rd pixel, and the last 8th-bit data is displayed together on SF8s in the 4th and 5th pixels. In this manner, the image blur on the retina becomes minimized, as shown in Fig. 3(c). As a result, the DFC noise is reduced. Because the image data for a 1TV field at 60 Hz are decomposed into bit data and rearranged on the 8 SFs, an approximate 480-Hz drive effect is obtained by using the proposed technology.

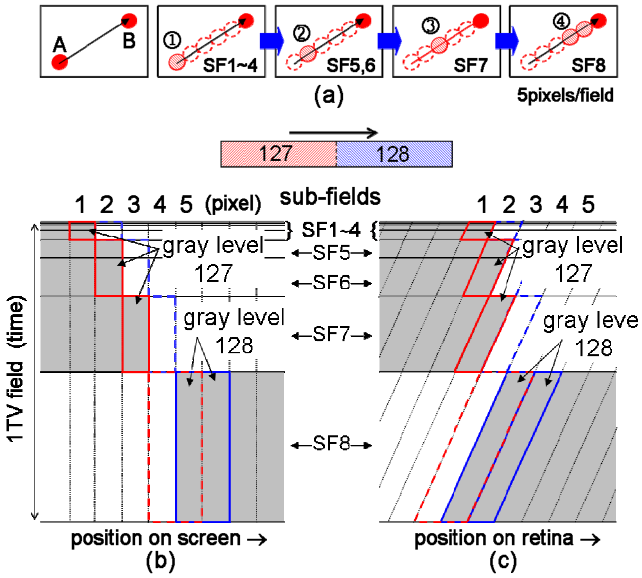

Fig. 3. Principle of pseudo 480-Hz driving method with simulation: (a) Conceptual diagram to explain the principle of proposed method; (b) 1TV field structure of proposed method on the screen; (c) Simulated results of image shape perceived on the retina.

4. Simulation results and Discussions

In order to verify the feasibility of the proposed technology, a DFC-noise simulator applying the abovementioned DFC-noise recognition model has been developed. The simulation procedure is as follows:

(1) Convert the image data into a pixel matrix of the on-screen horizontal position (x) × time of 1TV field (y).
(2) Divide the 1TV field into 8 SFs with bit weights and assign the bit data of the pixel on the SFs according to the gray level of the pixel.
(3) Set the moving speed of the image.
(4) Determine the rearrangement structure of the bit data assigned to SFs depending on the moving image speed.
(5) Rearrange the bit data of the pixel on the 8 SFs (Fig. 3(b)).
(6) Convert the pixel matrix into a parallelogrammic shape that is slanted to an extent that matches the moving speed (Fig. 3(c)).
(7) Obtain the DFC matrix of x × 1 by adding up each column (= time of 1TV field (y)) of the pixel matrix.
(8) Calculate the peak signal-to-noise ratio (PSNR)

The PSNR used to evaluate the DFC noise is defined as follows [14].

$$\mathrm{PSNR(dB)} \cong 10\log_{10}\frac{255^2\cdot\text{number of pixels}}{\sum_{i=1}^{n}(\text{DFC noise})^2} \qquad (1)$$

To gain the highest PSNR at the given speed of the moving image, a rearrangement combination of the image data on the SFs has been obtained using this simulator. Fig. 4 shows the simulated results of the DFC noise perceived on the retina when a gray bar consisting of 256 pixels in which the gray level increases horizontally from 0 to 255

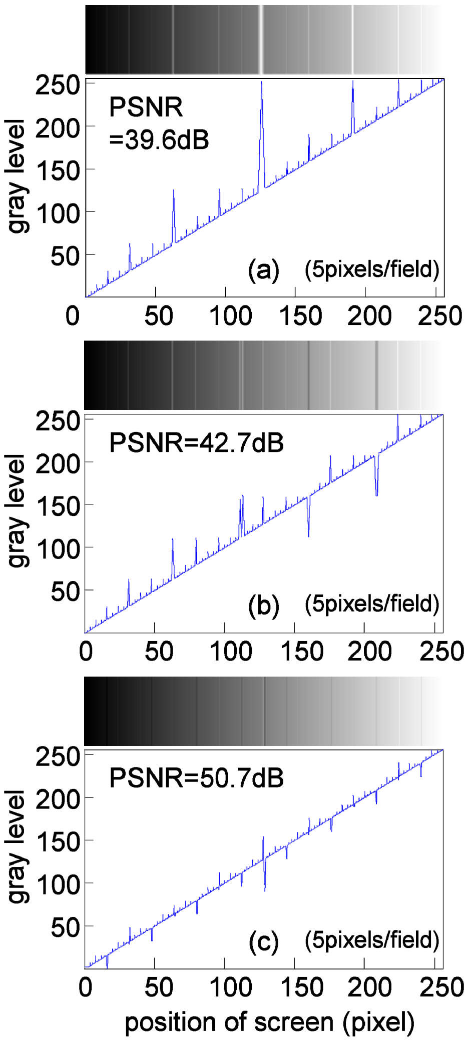

Fig. 4. Simulation results of the DFC noise perceived on the retina: (a) Simple field structure of 8-bit 8SFs (Fig. 1(a)); (b) Divided MSB and location shift structure of 8-bit 10SFs (Fig. 1(c)); (c) Proposed field structure of 8-bit 8SFs (Fig. 3(b))

in steps of 1 moves from left to right at a speed of 5pixels/field. Fig. 4 shows the results of the computer simulation performed to compare the conventional method with the method proposed in this study for DFC noise reduction. Fig. 4(a) shows the results of the simulation of the image with a simple field structure of the 8-bit 8 SFs shown in Fig. 1(a). Fig. 4(b) shows the simulation results of the image with the conventional structure of 8-bit 10 SFs shown in Fig. 1(c). Fig. 4(c) shows the results of the simulation of the image with the proposed 480-Hz structure of 8-bit 8SFs shown in Fig. 3(b). The arrangement of the pixel data with the structure of 8-bit 8 SFs has been optimized using the DFC noise simulator. The PSNR ratios were (a) 39.6 dB, (b) 42.7 dB, and (c) 50.7 dB, and the proposed method gained the highest ratio.

Fig. 5 shows the results of simulation obtained to compare the DFC noise observed in the proposed method with that observed in the conventional method at various speeds of the moving gray bar. The DFC noise increased with the speed of image in the conventional methods. On the other hand, to gain the highest PSNR value at the given speed of the moving image, the rearrangement combination of the image data on the SFs has been optimized by using DFC noise simulator in the proposed method. As a result, a considerably higher PSNR values was obtained using the proposed method than using conventional methods, just using only 8 SFs. In this manner, the DFC noise is effectively reduced without decreasing the brightness of image.

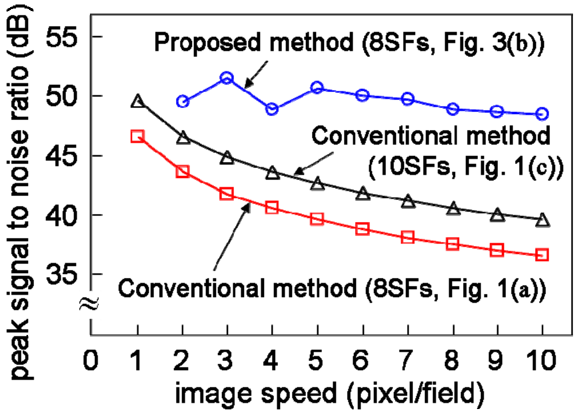

Fig. 5. Simulation results of the DFC noise at various speed of moving gray bar image

Table 1. Optimized data rearrange structure of pseudo 480Hz method

speed	Rearranged pixels									
(p/f)	1	2	3	4	5	6	7	8	9	10
2	1-7	8								
3	1-6	7	8					8 sub-fields		
4	1-4	5,6	7	8						
5	1-4	5,6	7	8	8					
6	1-5	1-5	6	7	8	8				
7	1-5	1-5	6	7	8	8	8			
8	1-4	1-4	6	7	7	8	8	8		
9	1,2	1,2	3-5	6	7	7	8	8	8	
10	1-3	1-3	4,5	6	7	7	8	8	8	8

Table 1 shows the rearrangement structure of the pixel data in SFs optimized with up to 10pixels/field using the computer simulation. The rows list the pixel positions on the screen, while the columns list the speed of the moving image. The numbers in the table indicate the pixel to which each of the 8 SFs should be assigned. For example, if the image speed is 5pixels/field, the bit data of the image assigned to the 1st to 4th SFs are displayed in the original position of the pixel, but the bit data assigned to the 5th and 6th SFs are displayed in the next pixels. The bit data assigned to the 7th SF is displayed in the third pixel, and the bit data assigned to the 8th SF is displayed in the fourth and fifth pixels together.

Finally, unless human eyes accurately trace the movements of image, this method can create some noise for certain combinations of gray levels. However, human eyes clearly recognize only the image in the center of retina and tend to neglect the images formed around the edges. Therefore, in this case, image noise is hardly recognized.

5. Conclusion

In this study, a new pseudo 480-Hz drive method has been proposed to reduce the DFC noise that occurs on the FPDs with displaying gray scale in the digital mode, such as PDPs. The proposed method makes the movements of image nearly continuous by rearranging the 8-bit data of the image displayed for 1TV field into 8 SFs. The position of the image data rearranged in SFs has been optimized on the basis of the speed of the moving image by computer simulation of the DFC noise. From the results of the study, it is verified that a significant reduction in the DFC noise is achieved with the proposed method as compared to conventional noise reduction technologies. Moreover, to reduce the DFC noise in digital mode displays, conventional technologies require more than 10 SFs whereas the proposed technology requires only 8 SFs. Therefore, there is no reduction in the brightness of the image when the DFC noise is reduced. The proposed method can be easily implemented by applying a new algorithm that rearranges the image data to SFs by predicting the image movement, to the signal processing unit. Further, because it is unnecessary to change the hardware or driving method of FPDs, no additional development costs are incurred. This technology can be applied to all FPDs that use digital methods for presenting grayscale images.

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