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Two-stage dither to enhance gray scales based on real-time motion detection in plasma display panel

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In order to reduce gray scale loss in low and middle-high gray scale ranges which are caused by inverse gamma conversion and limited gray scale method for dynamic false contour (DFC) improvement, respectively, and enhance gray scales both in static and moving regions of an image, two-stage dither based on real-time motion detection method is proposed. Firstly, the image is divided into blocks, and the motion state of each image block is detected according to real-time motion detection method. So limited gray scale method to improve DFC can only be used in moving image blocks. Then, ordered dither and random dither combined with minor pixel separation (MPS) are used to improve gray scale loss caused by inverse gamma conversion and limited gray scale method, respectively. The experimental results show that motion detection can be implemented easily and the detection accuracy is more than 99.3%. The gray scales in moving and static image regions are all expressed smoothly while DFC is markedly improved.

1. Introduction

Inverse gamma conversion is necessary for plasma display panel (PDP) and gray scale loss will occur, especially in low gray scale range [1]. Dynamic false contour (DFC), a serious problem in PDP, is usually improved effectively by using limited gray scale method [2,3]. However, it can cause gray scale loss, especially in middle-high gray scale range.

Gray scale enhancement is needed for reproducing gray scale loss. Dither is one of the most effective methods to reproduce the gray scales and smooth the luminance among these gray scales which cannot be displayed directly [4]. Dither noise can be reduced by varying dither mask according to the motion vector. However, the motion vector algorithm is complex and high cost to implement in real time for consumer electronics [5]. Subfield dither algorithm can reduce the structural pattern in two smallest-weight subfields with an additional subfield [6]. The structural pattern will occur when error diffuse combined with ordered dither is used for a motion image and image quality in middle-high gray scale range may be worse [7]. Dither algorithm using multi-threshold level can improve the luminous distribution both in spatial and time domains. However, at specific gray scales (e.g. the value of fraction is 1/4 after data conversion), it will induce structural pattern and deteriorates image quality seriously [8]. Different dither methods may cause different dither noise at different gray scale ranges. Besides, minor pixels (MP) which causes uncomfortable visual perception are easily brought by dither or error diffusion for gray scale enhancement [9].

When limited gray scale method is used to improve DFC in the whole image without distinguishing moving or static image regions, poor gray scale expression in static image regions will be brought [10,11]. The complexity and cost of motion detection methods such as new diamond search, novel four-step search, and new three-step search are too high to apply in PDPs although these methods can obtain velocity and direction of movement accurately [12–14]. Therefore, lower cost and easier implementation are the key issues for motion detection in DFC improvement.

Two-stage dither method based on real-time motion detection is proposed to improve gray scale expression in the whole gray scale ranges and reduce dither noise both in static and moving image regions. First, an image is divided into blocks and motion state of each image block is detected according to the brightness differences among image frames. In order to improve DFC occurred in moving regions and ensure the gray scale expression in static regions simultaneously, different numbers of gray scales are applied in the two kinds of image regions, respectively. Then, the two-stage dither combined with minor pixel separation (MPS) is used to enhance the gray scales according to the characteristics of gray scale loss caused by inverse gamma conversion and DFC improvement. The experimental results show that the motion detection is easy to implement and its accuracy can reach 99.3%.

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The gray scales after inverse gamma conversion and limited gray scale method are both expressed smoothly without periodic dither noise and minor pixels.

2. Gray scale noise in PDPs

2.1. Gray scale loss

The output gray scales are compressed into a narrow gray scale range after inverse gamma conversion, and gray scale loss is brought. The limited gray scales are used to improve DFC. For example, **GRAY** is a set of the limited gray scales including [0 1 2 4 5 8 9 14 17 23 26 28 37 41 44 58 64 68 71 90 99 105 109 134 148 157 163 166 197 214 228 237 242 255]. Therefore, input gray scales 0 to 255 can only be expressed by **GRAY** and it also cause gray scale loss.

Assuming l_0 is the brightness value of one gray scale and the background brightness g_0 is equal to l_0, g_i is the gray scale after inverse gamma conversion. The brightness of gray scale g_i is $l_0 + g_i \times l_0$. According to the Weber Law, human vision system is sensitive to the relative error of brightness differences. The relative errors r_1 and r_2 caused by inverse gamma conversion and limited gray scale method, respectively, are calculated by (1).

$$\begin{cases} r1 = \frac{g_i - [g_i]}{[g_i] + l_0} \\ r2 = \frac{[g_i] - g_n}{g_n + l_0} \end{cases} \quad (1)$$

where i is from 0 to 255. Integer part of g_i is $[g_i]$. N is the number of gray scales in **GRAY**, g_n is the gray scale in **GRAY**, and $g_n < g_i < g_{n+1}$, n is from 1 to N.

Different gamma and limited gray scales will cause different relative errors. We set gamma as 2.2 and limited gray scales as **GRAY**, respectively. The relative errors calculated by (1) are shown in Fig. 1. We can find that the relative error caused by inverse gamma conversion in the low gray scale range about 0 to 60 is much higher than that in the middle-high gray scale range over 60. When using limited gray scales for DFC improvement, gray scale loss mainly occurs in the middle-high gray scale range about 55 to 255. It means that the gray scale loss is always much more easily perceived by human vision system both in the low gray scale range after inverse gamma conversion and in the middle-high gray scale range after limited gray scale method.

2.2. Dither noise

Dither is as effective method to improve gray scale loss and reproduce gray scales. Assuming gray scales 4 and 8 can be displayed directly in PDPs, gray scale 5 can be expressed with three gray scales 4 and one gray scale 8 by using spatial brightness mixture shown in Fig. 2. Gray scales 6 and 7 can also be expressed using the same way. Dither mask is very important in dither

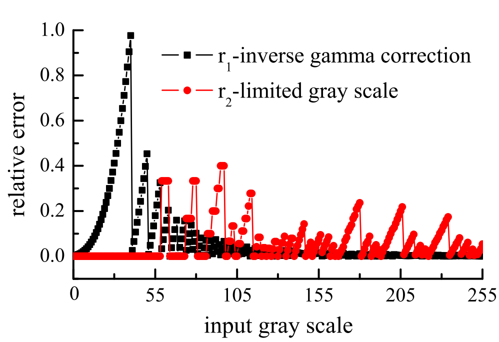

Fig. 1. Relative error of brightness differences caused by inverse gamma correction and limited gray scale method, respectively.

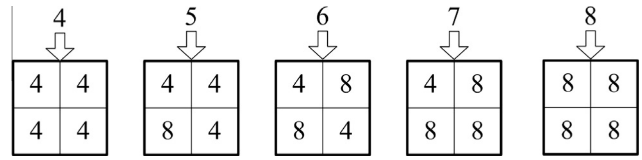

Fig. 2. Gray scale expressed by dithering.

method. The random dither mask and ordered dither mask are usually used in PDPs, which are composed by a series of random numbers and certain matrix, respectively.

(1) The characteristic of ordered dither noise.
Bayer matrix is always as ordered dither mask, and the regular stripe shown in Fig. 3(a) is brought in static image because of the cyclical and certain dither mask. When realizing some certain gray scales (such as 1/4) in moving pictures by ordered dither, another kind of regular lattice pattern will appear as shown in Fig. 3(b). These dither noises can be eliminated by using different dither masks according to the image motion vector. However, the image motion vector detection is high cost and complex to apply in PDPs.
(2) The characteristic of random dither noise.
Random dither uses a series of random numbers as dither mask. When the width of random numbers is the same as the image gray scale decimal fraction, all the gray scales can be represented by decimal fraction of image gray scale in theory. Gray scale 8 realized by random dither is shown in Fig. 4 and no regular pattern noise occurs. However, bright or dark areas can easily gather together because brightness distribution after random dither is not so uniform.
(3) Noise caused by minor pixel.
The brightness of some pixels is much higher or lower than other adjacent pixels when dither method is used for gray scale enhancement. These brighter or darker pixels are called minor pixels (MP) [9]. As shown in Fig. 2, when realizing gray scale 5, the pixel with gray scale 8 is brighter than other adjacent pixels and is called MP. Likewise, the pixel with gray scale 4 is darker than other pixels and is also called MP when realizing gray scale 7. Minor pixels can easily be brought in dither. As human vision system is sensitive to the non-uniform gray scales, MP is easily perceived and cause serious dither noise.

3. Two-stage dither based on real-time motion detection to enhance gray scales

The implementation flow of proposed method is shown in Fig. 5. First, the motion state of each image block is detected by the real-time motion detection method. According to the motion detection results, we use limited gray scales (limited gray scale method) in moving image regions to achieve DFC improvement, and 256 gray scales in static image regions to keep static image rendering. Then, two-stage dither (ordered dither and random dither) combined with MPS are used to enhance gray scales. Ordered dither combined with MPS is used to improve gray scale loss caused by inverse gamma conversion, and random dither combined with MPS is used after limited gray scale method because non-uniform brightness distribution and the gray scale loss mainly occur in middle-high gray scale range.

3.1. Real-time motion detection

An image moving from right to left at different frames are shown in Fig. 6. We assume that the brightness calculation value