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Error Diffusion Method for Improvement of Gray Scale Rendition in PDP

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Abstract: This paper proposes an error diffusion method for improvement of gray scale rendition in plasma display panel(PDP). The conventional error diffusion method in PDP, which includes data separation for display and error part, may have a danger of wrong calculation of error to diffuse. The proposed approach suppressed the halftone artifact by calculating the error using the gray level itself. Thus, the proposed method accurately reproduces the gray level by driving the average error to zero. Experimental results, obtained using two benchmark images, nine well-known test images, and 104 random HDTV images, illustrated that the proposed method has smaller halftone artifacts than the conventional method does.

1. Introduction

Plasma display panel(PDP) has a new kinds of artifact, dynamic false contour(DFC), which appears as the disturbances of gray levels and colors in the form of an apparition of colored edge in the picture when the observation point on the screen moves[1]. To reduce this DFC, most PDP system use a limited number of gray levels for subfield mapping[2][3]. That is, these methods do not use the gray levels that are likely to cause the DFC. Thus, PDP system requires halftone technique such as error diffusion to represent insufficient gray levels. However, halftone technique induces unpleased noise called halftone artifact. Nowadays, the halftone artifact, as with DFC, becomes one of the serious problems of PDP image quality[4].

Halftoning is the process of representing continuous-tone input image with bi-level output image. Example includes conversion of an 8-bit grayscale image to a binary image, which is shown in Fig. 1. When devices have multi-level outputs, the halftone technique can easily be generalized to utilize this new capability. Assume an input image *i(x, y)* has *p* different levels and the device has *q* possible output levels. Then, the multitone(or multi-level halftone) process can be given by the following equation:

$$o(x,y) = INT[\frac{i(x,y)\times(q-1)}{p-1}+0.5] \quad (1)$$

where *o(x, y)* is the output value, and *INT[]* indicates integer truncation[5]. As shown in Fig. 2, this simple extension of halftone process with multiple output levels is defined as the multitoning scheme. This multitone process can be simply implemented using halftone process and one adder, as shown in Fig. 3.

Among the halftone techniques, this paper targets on Floyd and Steinberg error diffusion method[5], which is currently the most popular halftone technique. Error diffusion produces halftone image of much higher quality than classical dithering[7]. The term *error diffusion* refers to the process of diffusing the quantization error along the path of the image scan. An important point to emphasize is the fact that error diffusion accurately reproduces the gray level in a local region by driving the average error to "zero".


Figure 1. Example of halftone image.

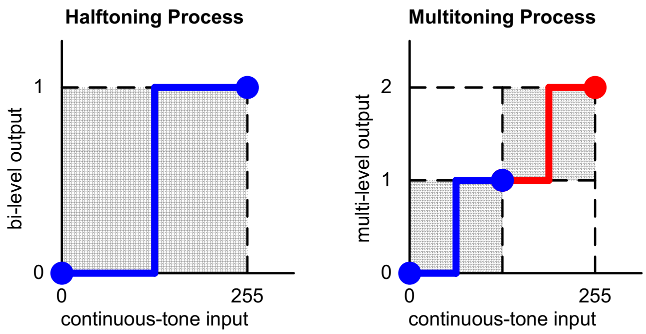


Figure 2. Concept of multitone by extension of halftone.

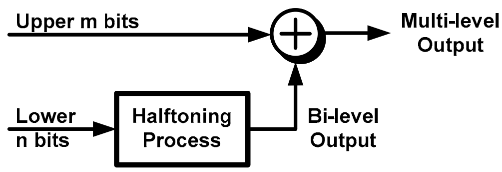


Figure 3. Implementation of multitone using halftone process and one adder.

However, since the conventional error diffusion method in PDP includes the data separation for *display* and *error* part, it can not drive the average error to "zero". Thus, there may be unpleasing artifacts on the displayed image. In Sect. 2, we discuss the conventional error diffusion method in PDP and propose a new approach to calculating the error for the error diffusion. Section 3 shows the experimental results. Finally, Section 4 concludes this paper.

2. Error Diffusion Method in PDP

The gray levels in PDP are realized from subfield mapping data with subfield weight number of plasma discharges. Since the subfield mapping data just indicate which subfield is "on" or "off" for display, the operation of error

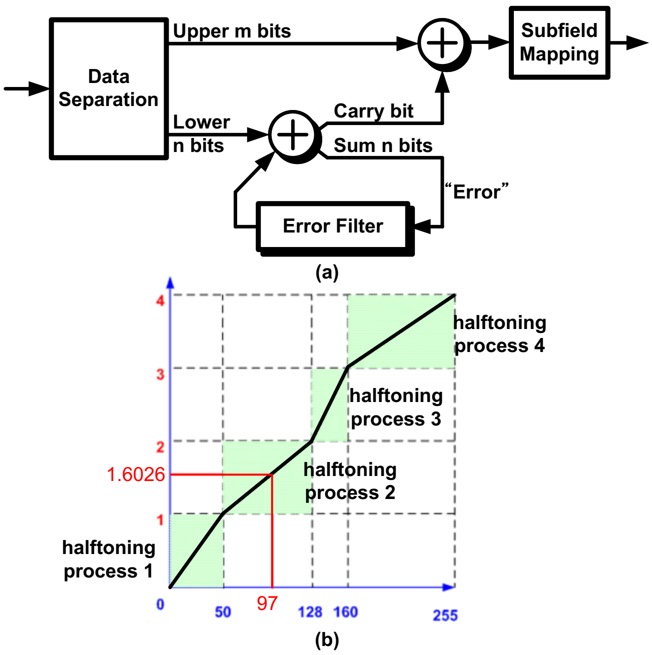


Figure 4. Conventional error diffusion method in PDP (a) and its non-linear mapping of data seperation block (b).

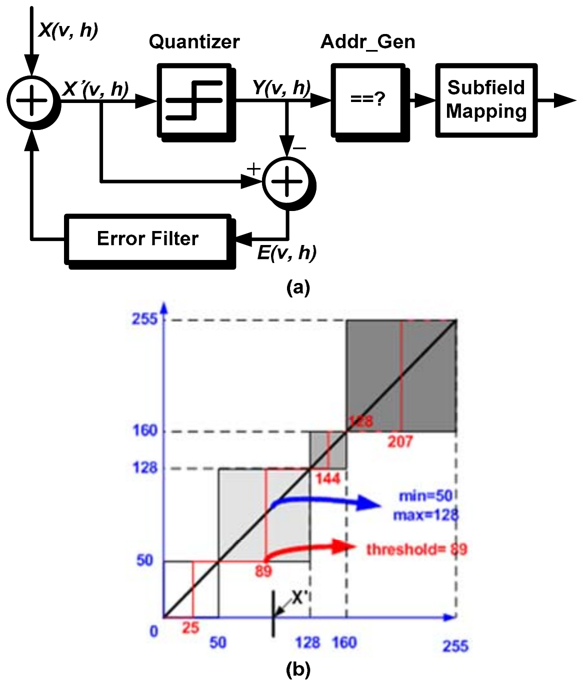


Figure 5. Proposed error diffusion method in PDP.

diffusion process can not be done after subfield mapping process. Thus, error diffusion should be done before subfield mapping process, and the output of conventional error diffusion method in PDP is look-up table(LUT) address for subfield mapping. However, the gray levels optimally selected to reducing DFC do not have a regular interval such as {0 4 8 12 … 248 252}, the conventional error diffusion method for PDP system requires a non-linear mapping for error calculation to follow the implementation scheme described in Fig. 3.

Figure 4 shows the block diagram of conventional error diffusion method in PDP and an example of its non-linear mapping process. For the simplified explanation, we assume that only 5 gray levels such as {0, 50, 128, 160, 255} are used to display. In this case, the subfield mapping LUT has 5 subfield data for each gray level. Each LUT address from 0 to 4 is final output of error diffusion block. When the gray level of current processing pixel is 97, for example, the output can be '1' or '2' for gray level 50 or 128, respectively. Actually, it is calculated by interpolation as '1.6026', which means more close to 128. The data separation block in Fig.4-(a) generates real number like '1.6026', and sends upper m bits of integer part '1'(*display part*) and lower n bit of decimal part '0.6026'(*error part*) to the error diffusion block separately. The decimal part is added with propagated errors from neighboring pixels, and then, the result, sum n bits in figure, will be propagated for next calculation. The carry bit indicates the bi-level output of error diffusion process. Finally, the output of error diffusion is determined by adding integer part and carry bit.

The data separation process in conventional method helps using simple implementation scheme of Fig. 3. However, since the actual meaning of "error part" from data separation can vary at every pixel, it may calculate wrong error. For example, the meaning of error part of '0.5' is gray level difference of 39 at the region between gray level 50 and 128, and also 16 at the region between 128 and 160. This means that the same error value is not actually the same difference of gray level. In this conventional error diffusion method, since the error value will be propagated and used for next error calculation, as mentioned above, there is some danger of wrong error calculation which makes unpleasing artifacts on the displayed image.

In this paper, we propose a new approach to calculating the error for the error diffusion method in PDP, which is free from the quantization error coming from the non-linear mapping of the conventional error diffusion method. Figure 5 shows a schematic diagram of proposed error diffusion method and the operation of its quantizer. In the proposed error diffusion method, the input gray level itself is used for quantization and calculation of error. Thus, proposed error diffusion accurately reproduces the gray level in a local region by driving the average error to "zero", the same as original error diffusion.

The output value of a pixel will be quantized to the nearest level. After each pixel is quantized, the error between the modified and quantized pixel values is computed. Mathematically, the proposed method may be described as follows:

$$X'(v, h) = X(v, h) + \sum W_i \bullet E_i \quad (2)$$

$$E(v, h) = X'(v, h) - Y(v, h) \quad (3)$$

where $X(v, h)$ denotes the original image, $X'(v, h)$ the modified image, $W_i \bullet E_i$ the weighted error from neighboring pixel, and $E(v, h)$ the error value for propagation.

The output value at the (v, h)-th pixel location is determined by quantizing the modified image at that location described as following Eq.(4).

$$Y(v, h) = Q[X'(v, h)] \quad (4)$$

where $Q[]$ denotes a particular quantizer. In an explicit expression, Eq.(4) becomes as follows:

$$Y(v, h) = q_1, \text{ if } X'(v, h) < T_1$$
$$Y(v, h) = q_2, \text{ if } T_1 <= X'(v, h) < T_2$$
$$\ldots\ldots$$
$$Y(v, h) = q_n, \text{ if } T_{n-1} <= X'(v, h) \quad (5)$$

where q_i is the i-th output level and T_i is the i-th threshold value. The threshold values are taken as the mid-point between two consecutive levels.

Since the input gray level itself is used for quantization and error calculation in the proposed method, the output value of proposed error diffusion is also gray level. The *Addr_Gen* block in Fig. 5 translates the gray level output from previous error diffusion to address number of subfield mapping LUT. When compared H/W costs of proposed method with that of conventional method, since the *quantizer* and *Addr_Gen* block can be implemented using small comparators, the proposed method requires less H/W resources. The data separation block, on the other hand, can be implemented using relatively big linear interpolation or LUT block.

3. Experimental Results

Experiments including subjective and objective test have been performed. We subjectively compared the halftone artifacts using two benchmark images and objectively evaluated the performance of the proposed error diffusion method using nine well-known test images, shown in Table 1, and randomly captured 104 HDTV images. The 39 gray levels listed in GCC code[3] are used in experiments as optimally selected gray levels to reduce DFC. The gray levels are described as following Eq.(6) :

39 gray levels listed in GCC
= {0, 1, 2, 4, 5, 8, 9, 14, 16, 17, 23, 26, 28, 37, 41, 44, 45, 58, 64, 68, 70, 90, 99, 105, 109, 111, 134, 148, 157, 163, 166, 197, 214, 228, 237, 242, 244, 255} (6)

To evaluate the performance, we used the objective method using the Peak Signal-to-Noise Ratio(PSNR) which represents the level of differences between the reference image and the processed image[8].

For the first experiments, we define two benchmark images mimicking the contents of natural images as shown in Fig. 6. The size of two benchmark images is 256x512 and the pixel number of each gray level is same as 512. The gray levels are regularly organized. Especially, we make the combination of horizontally-adjacent two pixels include all possible conditions, since the error coefficient to right-horizontal direction is 7/16 which is almost half of the error in Floyd and Steinberg error diffusion[5].

Figure 7 compares the *absolute difference image* between benchmark images and halftone images using proposed error diffusion method and conventional method. In this *absolute difference image*, the gray levels from 0 (black) to 255 (white) represent the absolute difference values from 0 to 51. The figure indicates that the proposed method induces less halftone artifacts since figure (b) and (d) have more unpleased grizzled regions than figure (a) and (c), respectively. For further details, the proposed

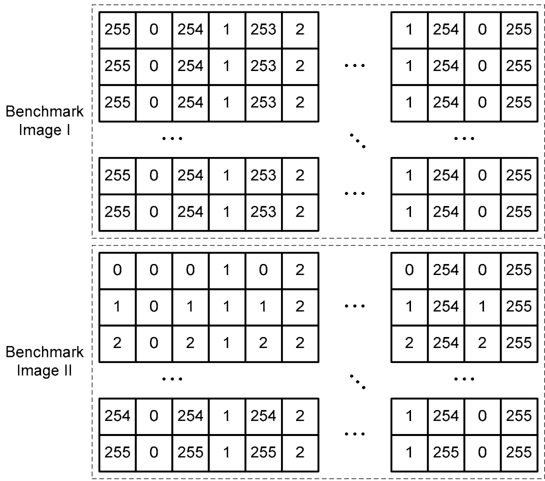
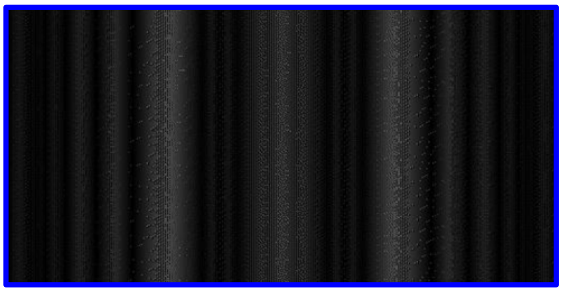
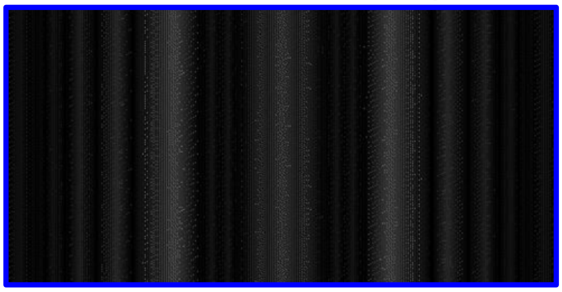


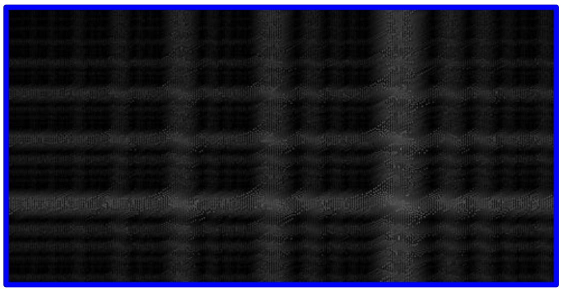
Figure 6. Benchmark image I (top) and II (bottom).



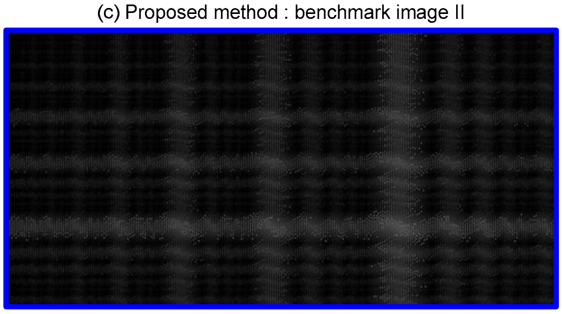
(a) Proposed method : benchmark image I



(b) Conventional method : benchmark image I



(c) Proposed method : benchmark image II



(d) Conventional method : benchmark image II

Figure 7. Experimental results : absolute difference images using benchmark image I (a)(b) and II (c)(d).

Table 1. PSNR comparison of artifact simulations.

	Proposed	Conventional	Improvement
Airplane	28.9475	28.6659	0.1816
Barbara	29.6201	29.3416	0.2784
Goldhill	30.0271	29.8923	0.1348
Lena	28.7723	28.6685	0.1039
Mandrill	28.1891	27.9709	0.2182
Monarch	29.0913	29.0585	0.0328
Peppers	27.8234	27.7457	0.0777
Tiffany	27.7260	27.6286	0.0974
Average of above 9 test images	29.1253	28.9823	0.1430
Benchmark image I	29.8762	29.1015	0.7747
Benchmark image II	29.5905	29.1239	0.4666
Average of 104 HDTV images	29.6561	29.5753	0.0808

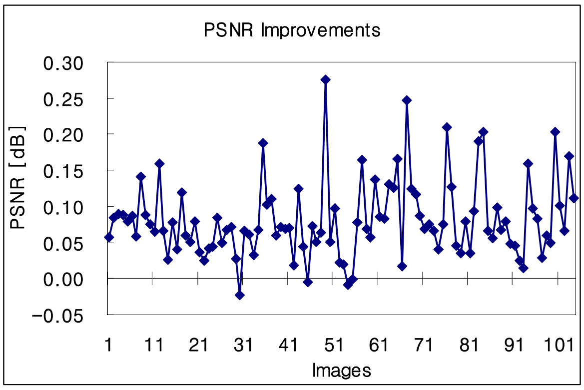


Figure 8. PSNR improvements [dB] of proposed method for 104 HDTV images

method exceeds in PSNR by 0.7747dB and 0.4666dB at benchmark image I and II, respectively.

Table 1 presents the experimental results obtained using nine popular test images and 104 HDTV images. For the HDTV images, average experimental values are provided in this table, and the detail improvements are shown in Fig. 8. The table and figure indicate that proposed method clearly outperforms the conventional method in halftone noise.

4. Conclusion

This paper presents a new approach to calculating the error for the error diffusion method in PDP. In the proposed error diffusion method, the input gray level itself is used for quantization and calculation of error to diffuse. Thus, proposed error diffusion accurately drives the average error to “zero”.

Experimental results, obtained using two benchmark images, nine well-known test images, and 104 random HDTV images, illustrate that the proposed error diffusion method is free from the quantization error coming from the non-linear mapping of the conventional method. It is concluded that the proposed method successfully reduces the halftone artifacts and provides the better gray scale rendition in comparison with the conventional method. When compared H/W costs with conventional method, the proposed method requires less H/W resources.

Acknowledgement

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