CONFINED ERROR DIFFUSION ALGORITHMS FOR DISPLAY DEVICE

Jun Hak Lee, Takahiko Horiuchi, Ryoichi Saito

Graduate School of Science and Technology, Chiba University, Japan

ABSTRACT

Until now, the structural pattern at the specific gray level or at the special condition of image data was mainly issued in dithering or error diffusion method. This problem was more critical in flat panel display because of the heavy intensity of unit luminance. One of the authors published a concept, "confining error-carry within the dither mask" as a patent, but we have not published about the technology in detail as a paper. Based on the concept, in this paper, at first, we propose an algorithm named "Confined Error Diffusion (CED)" which has the well organized architecture between random error diffusion and ordered dither method to improve the image quality and gray level expression for the flat panel display. Then, we propose an advanced CED algorithm to improve the problem of the CED related to the gradation. This algorithm can be adapted to flat panel display.

***Keyword*—**Image processing, Flat panel displays, Display human factors, Dither techniques, Algorithms

1. INTRODUCTION

Recently, many digital display devices have been introduced in the display market like Plasma Display Panel (PDP), LCD, etc. The image quality is more and more issued in product marketing for TV, Monitor. There are many factors for the image quality, halftone method, gray linearity, contrast ratio, color, sharpness, etc. Many digital halftone algorithms have been proposed such as Refs.[1]-[5]. The mainstream of the recent halftone method is the ordered dither and the error diffusion algorithm. But these algorithms were focused on the digital printing not on the display devices. In this paper, we propose a well organized halftone algorithm for flat panel display. This algorithm can be implement-ed in real time process and provide the high quality image.

Each flat panel display device has the original display characteri-stics depends on its own driving scheme or used material. For example, Plasma Display has the characteristics to express gray level, SF driving scheme, self-emissive, etc. Especially, low gray expression is important in plasma display because the lowest unit luminance is larger than that of any other display devices. The halftone pattern is more visible in low gray level region because of this reason. So, specially organized halftone process is needed to overcome the device dependent limitation.

In order to solve the problem, one of the authors suggested a concept in Patent [6]. Firstly, we propose an algorithm named the Confined Error Diffusion (CED) based on the concept. The CED algorithm can improve the structural pattern caused by error diffusion and dither process. But there is still some limitation to use in various kinds of scene. For example, the CED algorithm showed a good performance in static scene because of the uniformly distributed dither characteristics, but there is some point to improve in the gradation characteristics. So, as the next step, we propose an advanced CED (ACED) algorithm by introducing a linear transform process to the CED and using the well-matched random error diffusion algorithm. In remainder of the paper is organized as follows. In Sec.2, we explained the CED algorithm in detail. Then we propose the ACED algorithm in Sec.3. Section 4 will show results of the algorithm and comparison of our algorithm and conventional methods. Conclusion will be given in Sec.5.

2. CONFINED ERROR DIFFUSION ALGORITHM

2.1. Outline

The CED algorithm improves the structural pattern caused by dither pattern and error diffusion. Firstly, we separate the pixel data to upper packet (higher bit packet, 3 bit from MSB) and lower packet (lower bit packet, 5 bit from LSB) as shown in Fig.1. The higher bit packet is used for dither process and the lower bit packet is used for error diffusion process. And the next, we calculate the lower bit packet error carry with the specially organized random error diffusion process for each pixel. After that logical AND operation (Attachment) is carried out with the lower bit packet error carry and the highest bit of lower bit packet to produce 4bit dithering data including higher bit packet and the result of local AND operation. Finally, ordered dithering process is carried out in pixel by pixel.

Figure 2 shows the concept of the CED. The full pattern of 1 frame dither is shown. The odd pattern is selected by only dither-carry, the even pattern is selected by random error diffusion-carry and logical AND operation is carried out in pixel by pixel. This means

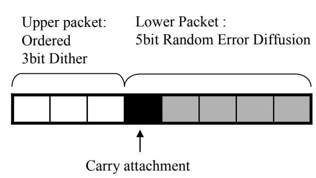


Figure 1: Bit structure of CED.

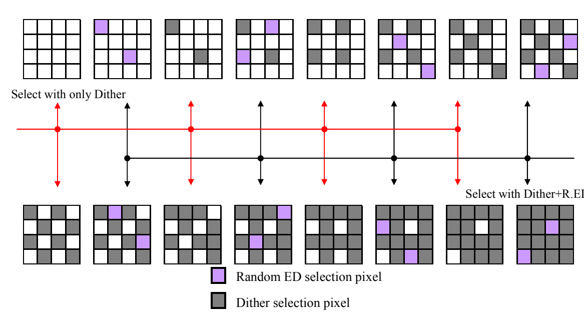


Figure 2: Concept of confined error diffusion

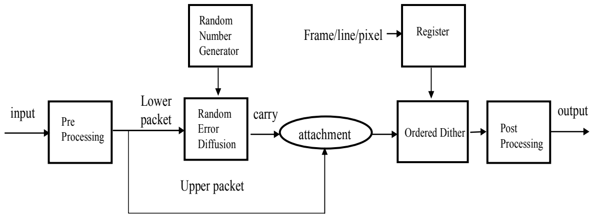
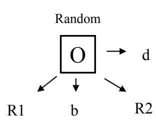


Figure 3: Block diagram of CED algorithm

the random error diffusion-carry is confined by upper level dither mask. More carefully, if the highest bit of lower bit packet is ‘0’ and the result of random error diffusion is ‘0’ at any pixel, the even mask is selected. If the highest bit of lower bit packet is ‘1’ and the result of random error diffusion is ‘1’at any pixel, the odd mask is selected by the ordered dither process. Figure 3 shows the block diagram of the CED algorithm. This block diagram is composed of two halftone process, random error diffusion block for lower bit packet and ordered dither block for higher bit packet. The ordered dither process contributes to make major rendering levels (ordered dither level) and the random error diffusion process contributes to make the intermediate (minor) rendering levels between the major rendering levels which were determined by the ordered dither process. This algorithm was implemented to real time processor and applied to the mass products of Plasma Display.

2.2. Random Error Diffusion Process

Figure 4 shows the concept of random error diffusion used in the CED algorithm. The procedure of rendering is similar to conventional Floyd-Steinberg algorithm except that the coefficients are randomly calculated by internal pseudo-random number generator like formula.



R1 is generated by random number generator.
R1+b+R2+d=1
R1+R2=Limit
Limit<0.8
b=(1-Limit)*0.25 : d=(1-Limit)*0.75

Figure 4: Concept of Random Error Diffusion in CED algorithm

2.3. Ordered Dither Process

In the CED algorithm, 4 kinds of dither masks are used to render the artificial gray level such as Fig.5. The possible pattern sets, can be generated from these dither masks dependent on the input gray level, are shown in Fig.6. The dither mask sets are generated with frame/line/pixel position. The dither carry is determined by comparing with the binary index 0000~1111 and highest 4bit data including the higher bit packet and the result of random error diffusion. We used the concept that well distributed mask, time-spatial, can make the fine gray expression. In any display device, flicker problem is very critical. Because we use the 4 frame dither mask toggle concept, we must consider the time-spatial relation to generate the dither masks. Total sum of ON-OFF state is specially balanced with the time-spatial domain as shown in Fig.6. We can improve the flicker characteristics using this time-spatially well-balanced dither masks. In this manner, we can improve the structural pattern caused by error diffusion and dither process. But there was still some limitation to use in various kinds of scene. For example, the CED algorithm showed a good performance in static scene because of the uniformly distributed dither characteristics, but there is some point to improve in the gradation characteristics.

Frame N

8	3	11	0
7	14	4	13
10	1	9	2
5	12	6	15

Frame N+1

13	7	14	5
0	11	3	8
15	4	12	6
2	9	1	10

Frame N+2

10	0	9	3
5	13	6	14
8	2	11	1
7	15	4	12

Frame N+3

15	4	12	7
3	8	0	11
13	6	14	5
1	10	2	9

Figure 5: 4x4 Ordered Dither Mask for 4 frame toggle

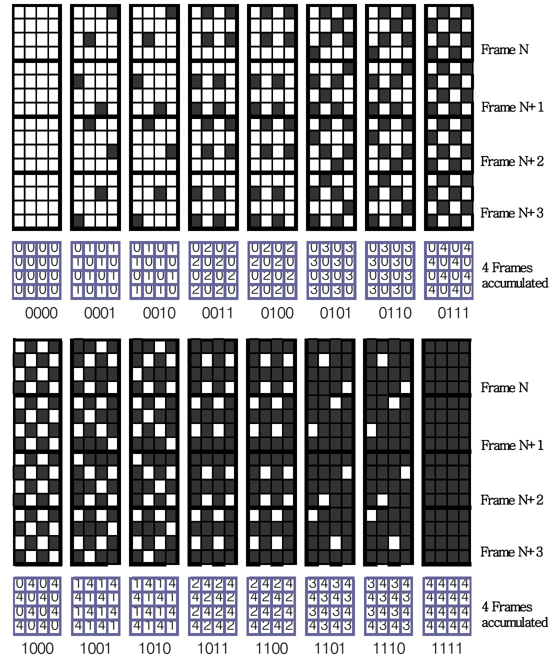


Figure 6: possible dither pattern for 4 frames from Fig.5

3. ADVANCED CONFINED ERROR DIFFUSION

In this section, we propose the advanced confined error diffusion algorithm (ACED) to improve the characteristics of the CED algorithm. The block diagram of the ACED is shown in Fig. 7. In the ACED algorithm, the linear transform process in Eq.(1) is added before processing the random error diffusion for lower packet data to improve gradation characteristics.

$$I_{out} = \frac{((2-A)\cdot I_{in} + A)}{B} \tag{1}$$

Where, I_{in} is the low bit packet data. The variables A ($0 \le A \le 0.4$) and B ($2 \le B \le 2.4$) can be adjusted by gradation. In this paper, variable A and B are experimentally determined as 0.2 and 2.2, respectively. The flat-area, caused by the random error diffusion

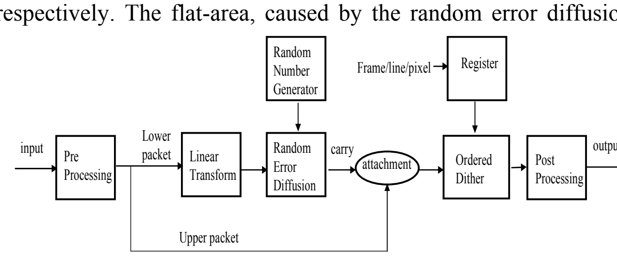


Figure 7: Block diagram of ACED algorithm

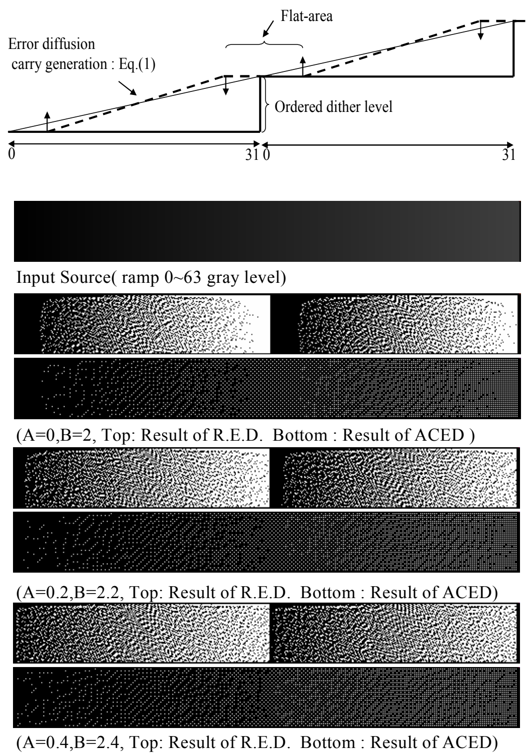
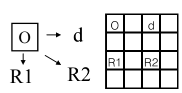


Figure 8: Flat-area control by linear transform: R.E.D. carry-generation control of lower bit packet



R1 is generated by random number generator.
R1+R2+d=1
R1+R2=Limit
Limit=0.75
d=(1-Limit)

Figure 9: Block diagram of proposed Random Error Diffusion

process of the lower bit packet, can be reduced using the pre-linear transform. We can control the carry-generation, slope of Eq.(1), of the random error diffusion of using low bit packet and reduce the flat-area as shown in Fig.8. The gradation of CED algorithm can be improved using this flat area control.

We also used the well-matched random error diffusion algorithm as shown in Fig.9. The position of generating carry can be confined by this type of error diffusion structure. The R1 is generated by pseudo-random number generator, R2 and d is automatically calculated using this R1 value by the criterion.

4. EXPERIMENTAL RESULTS

We compare the results of various kinds of halftone, Floyd-Steinberg, Ordered Dither, CED algorithm, ACED algorithm, with the source of “gradation ramp” image in Fig.10, and “Eagle” image in Fig.11. The size of “gradation ramp” image is 256x128 pixels and the image has the structure of increasing or decreasing, 1 gray level/4pixel. The results of the conventional halftone algorithm, Floyd-Steinberg error diffusion, Ordered Dither, is shown (b), (c) in Figs.10 and 11. These algorithms were focused on the digital printing, so the temporal display visibility was not considered. The error diffusion algorithm has a diagonal structural pattern, and this pattern can more visible in flat panel display like plasma display panel, because of the heavy intensity of unit luminance. And we must be careful of using dither algorithm in display device with the toggling concept, because the flicker problem can be easily arisen. The dither algorithm also has the problem for a lack of gray levels. The CED and ACED algorithms can improve the gray level expression using the concept of confining error-carry within the dither mask and reduce the flicker problem by using time-spatially well balanced dither mask. As shown (d), (e) in Figs.10 and 11, there is no structural pattern from the error diffusion or ordered dither algorithm. The lack of

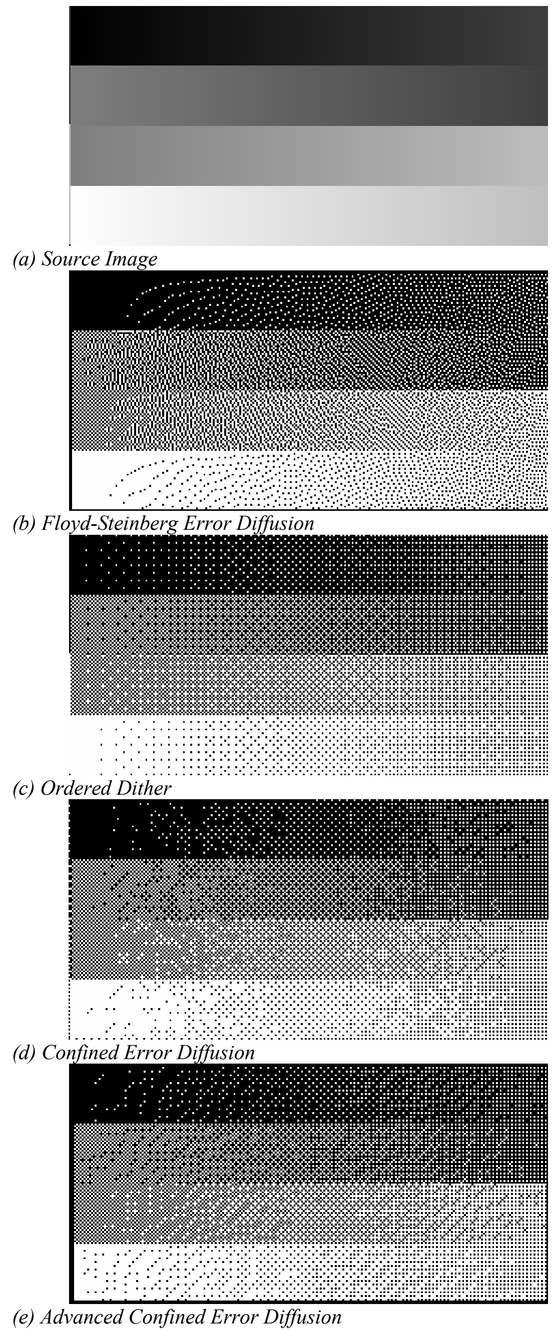
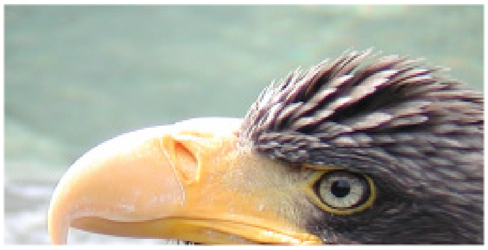
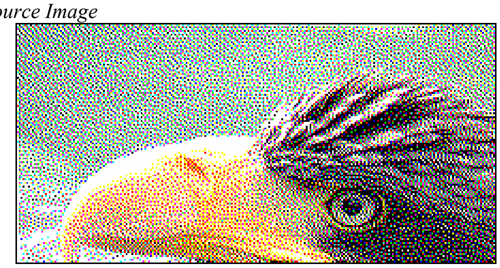


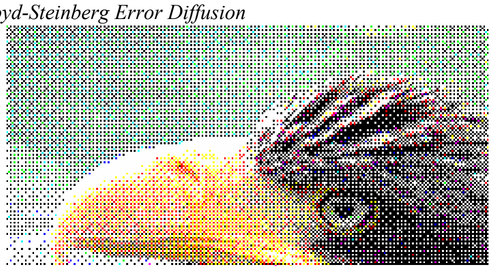
Figure 10: Results for a gradation ramp (1 frame image).



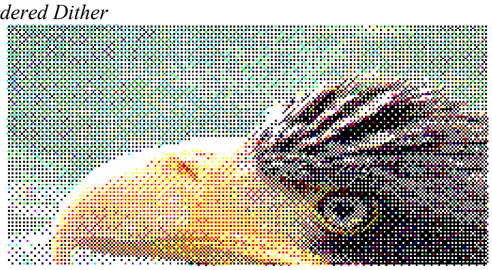
(a) Source Image



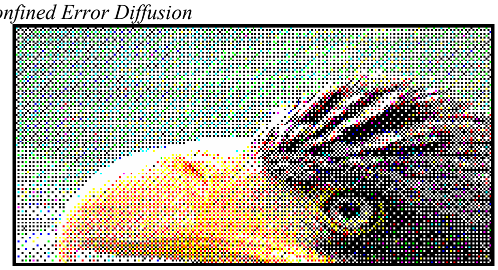
(b) Floyd-Steinberg Error Diffusion



(c) Ordered Dither



(d) Confined Error Diffusion



(e) Advanced Confined Error Diffusion

Figure 11: Result for Eagle (1 frame image).

gray levels for general ordered dither algorithm is also compensated using the random error diffusion process. The flat area of CED algorithm is also improved in the result of ACED algorithm. In spite of static image, the ACED algorithm provides the good gray expression as shown in Figs.10 and 11. The effect of full CED, ACED algorithms can not be shown in a static image, without 4 frame toggling concept. In Fig.12, 4 frame images and accumulated image are shown to discuss the 4 frame toggling effect. The effect of the averaged 4 frame image is not fully matched to the real 4 frame toggling effect. But the effect of accumulation in the eye can be explained.

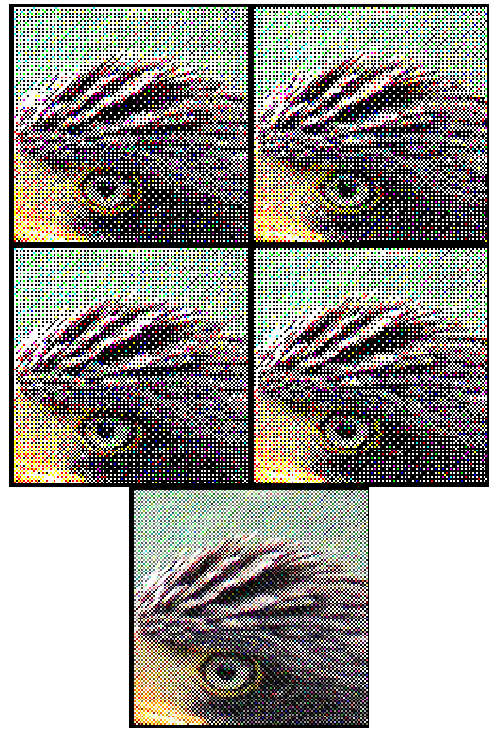


Figure 12: Results of ACED: frame N, N+1, N+2, N+3, and averaged image of 4 frames from top-left, top-right, middle-left, middle-right and bottom.

5. CONCLUSION

The ordered dither has the spatially well distributed characteristics. The error diffusion has the good characteristics for rendering the gray level. The proposed CED and ACED algorithms use these characteristics of dither, error diffusion for rendering the gray level. In this paper, we improved the gradation characteristics of the CED algorithm and reduced the structural pattern induced by error diffusion and dither. The time-spatially well balanced dither and random error diffusion has a good performance to solve the flicker problem in flat panel display devices.

REFERENCES

[1] B.Bayer, ”Color imaging array”, in U.S.Patent 3971065,1976.

[2] R.Floyd and L.Steinberg, “An adaptive algorithm for spatial gray-scale”, in Proceeding Society Information Display, 17(2), pp.75-78, 1976.

[3] Knuth, D.E. “Digital Halftones by Dot Diffusion”, ACM Transactions on Graphics, 6(4), pp.245-273, 1987.

[4] R.A. Ulichney, Digital Halftoning, Cambridge, MA: MIT Press, 1987.

[5] Pingshan Li and Jan P.Allebach, “Tone-Dependent Error Diffusion”, IEEE Transactions on Image Processing, 13(2), pp.201-215, 2004.

[6] Jun Hak Lee, Hwan Yu Kim, Dae Jin Myung, Geun Soo Lim, Jung Hwan Kim, “A method and apparatus for driving display panel”, in U.S.Patent 0140584,2005.