

A Look-Up Table Based Error Diffusion Algorithm for Dynamic False Contour Reduction of Plasma Display Panels

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Abstract

PDP(Plasma display panel) represents the gray levels by the pulse number modulation technique that results in undesirable dynamic false contours on moving images. This paper proposes a LUT(Look-up table) based error diffusion algorithm for reduction of the dynamic false contours. A quantitative measure of the dynamic false contours is defined first. The measure of the dynamic false contours is calculated through simulation of every gray level combination of two consecutive frames. Based on the calculated measures, a modified gray level for a pair of gray levels of two consecutive frames is chosen to reduce the dynamic false contours. The chosen gray levels serve as contents of a gray level conversion LUT. Given a pair of gray levels of two consecutive frames, the gray level of current frame is modified based on the gray level conversion LUT. The new gray level is displayed on PDP. An error diffusion algorithm is, then, applied to compensate for the differences in the gray levels.

Keywords : PDP, dynamic false contours, error diffusion.

1. Introduction

PDP represents gray levels by the pulse number modulation technique. This is suitable for representing gray levels of a still image. But, in the case of a moving image, it results in the degradation of image quality, which is often referred to as dynamic false contour [1]. Various techniques have been proposed to alleviate the dynamic false contours. They include the optimization of subfield pattern [2-3], adding equalizing pulses [4], compression of light emission time [5], and error diffusion methods [6].

The optimum selection of subfield pattern does not require additional hardware for implementation. But, the dynamic false contours are not sufficiently reduced by the optimization of subfield pattern itself. Thus, it is desirable to employ additional techniques to further reduce the dynamic false contours. Equalizing pulse technique is to add a pulse to the gray levels that are likely to generate the dynamic false contours. The amplitude of the added pulse is determined based on the gray level and motion vector. Even though it is reported to be effective in reducing the dynamic false contours, it involves complex computations to obtain complete information on motions. Compression of light emission time can alleviate the dynamic false contours. But, it also reduces the luminance level that should not be sacrificed. In the existing error diffusion based approach [6], only a subset of gray levels is displayed for an area of image in motion to avoid the dynamic false contours. Error diffusion is then applied to compensate for the differences between the displayed and original gray levels. Like equalizing pulse technique, it requires information on motion vector that is computationally

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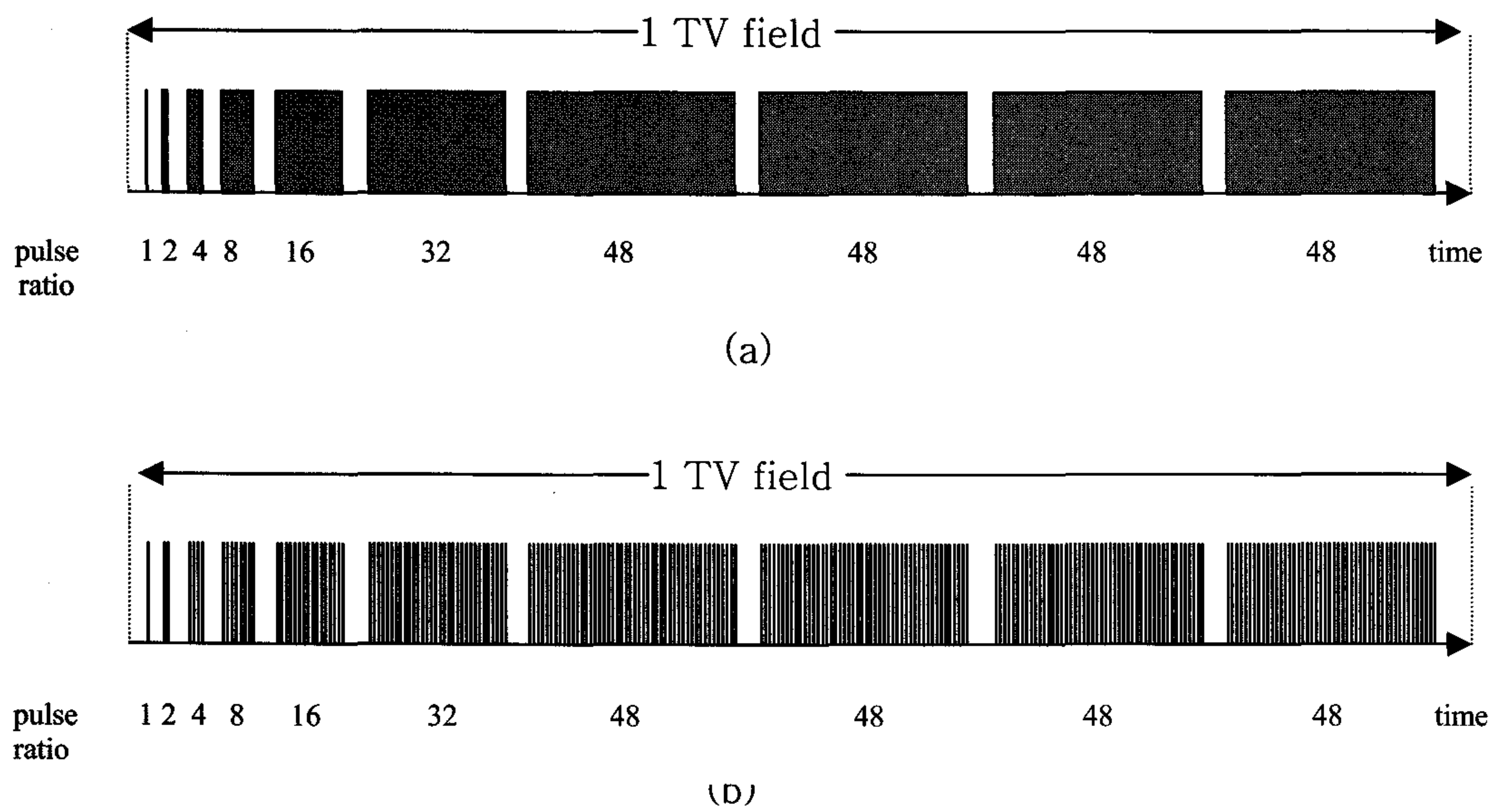


Fig. 1. An example of subfield pattern (a) real pattern and (b) imaginary pattern.

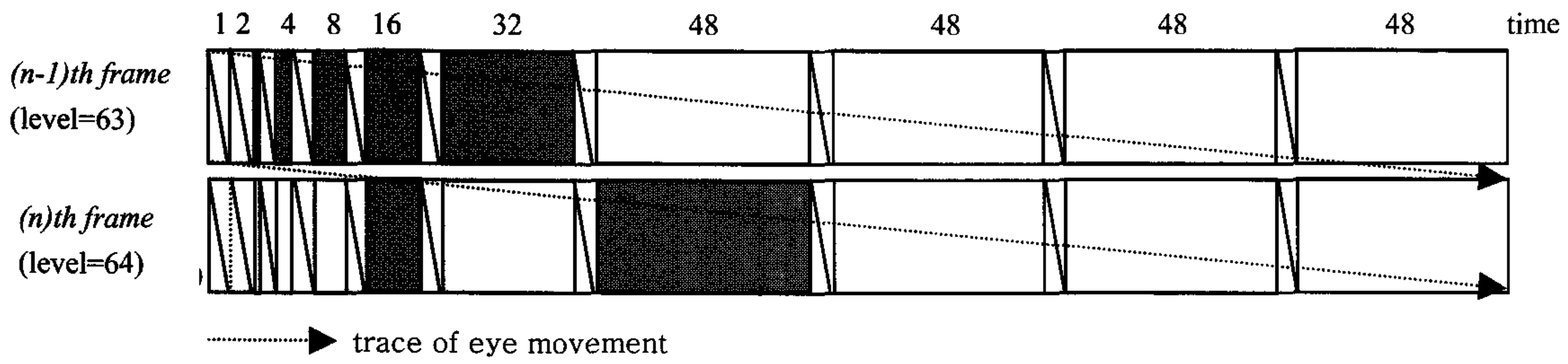


Fig. 2. An example of simulation with a real subfield pattern.

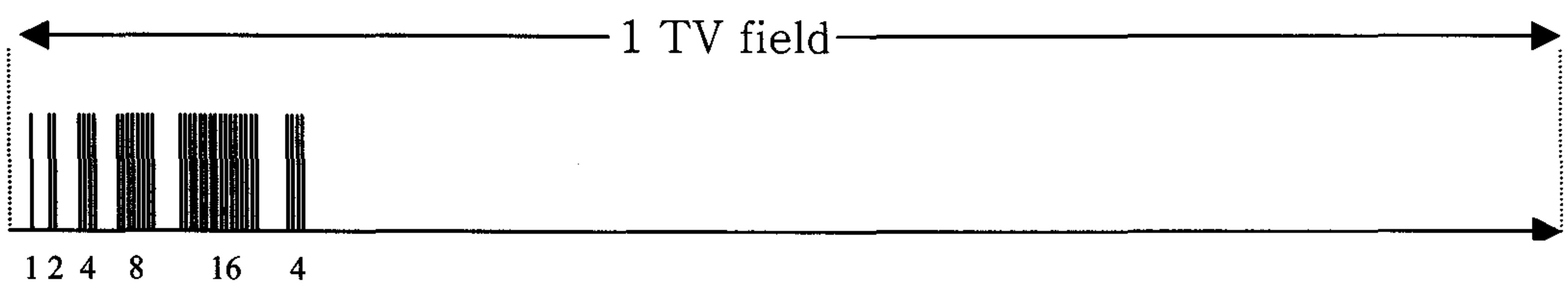


Fig. 3. Sustaining pulses for gray level 35 by imaginary subfield pattern in Fig. 1(b).

expensive.

In this paper, a new LUT based error diffusion algorithm is proposed for the reduction of the dynamic false contours. A quantitative measure of the dynamic false contours is defined first. The measure of the dynamic false contours is calculated through simulation of every gray level combination of two consecutive frames. An imaginary subfield pattern is also defined for the simulation. Based on the calculated measures, a modified gray level for a pair of gray levels of two consecutive frames is chosen to reduce the dynamic false contours. The chosen gray levels serve as contents of a gray level conversion LUT. Given a pair of gray levels of two consecutive frames, the gray level of current frame is modified based on the gray level conversion LUT. The new gray level is displayed on PDP. An error diffusion algorithm is then applied to compensate for the differences in the gray levels.

In Section 2, a quantitative measure and an imaginary subfield pattern defined for simulation are described. The proposed algorithm with the gray level conversion LUT is explained next. In Section 3, experimental results are presented. Discussions on the results are summarized in Section 4.

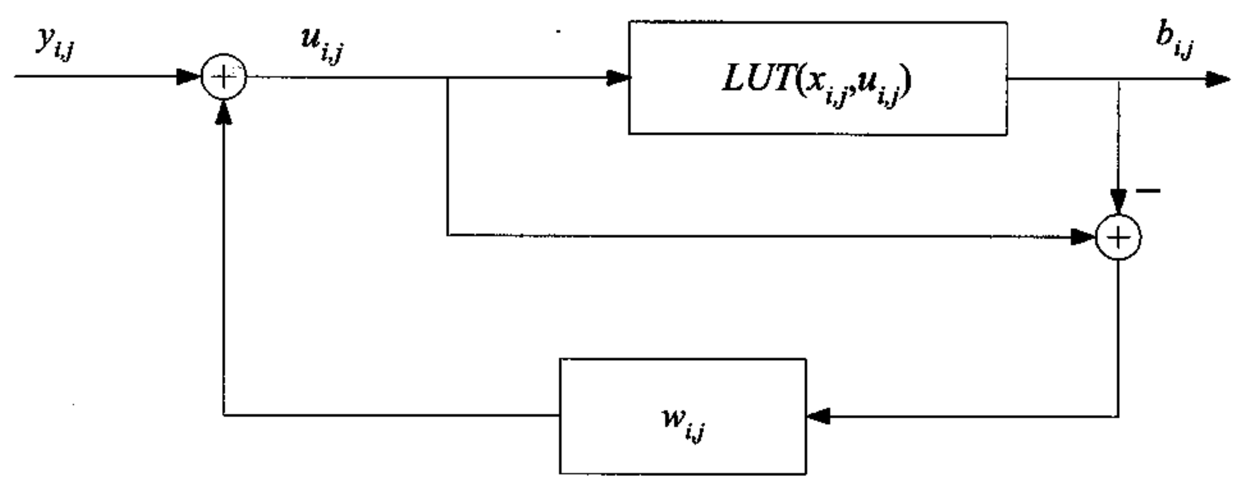


Fig. 4. Block diagram of proposed algorithm.

2. Proposed Algorithm

2.1 Simulation of dynamic false contours

In the proposed algorithm for reduction of the dynamic false contours, the gray level of current frame is modified based on the gray level conversion LUT constructed by off-line procedures. As a first step to construct the gray level conversion LUT, a simple quantitative measure for the dynamic false contours is defined as follows.

$$\text{contour}(x,y) = |\text{real}(x,y) - \text{imaginary}(x,y)| \qquad (1)$$

where x and y represent the gray levels of two consecutive frames, the (n-1)th and (n)th frame, respectively. real(x,y) denotes the simulation result with a subfield pattern that is actually employed for PDP. An example of real subfield pattern having pulse ratio [1 2 4 8 16 32 48 48 48 48] is shown in Figure 1(a). Simulation method [7] to obtain real(x,y) is shown in Figure 2 where the gray levels of the (n-1)th and (n)th frame are 63 and 64, respectively. imaginary(x,y) denotes the simulation result with an imaginary subfield pattern shown in Figure 1(b). Two subfield patterns in Figure 1 have the same addressing and sustain periods. But, each sustain pulse in an imaginary subfield pattern is assumed to be turned on successively according to the gray level. Figure 3 shows the sustain pulses to be turned on for gray level 35. imaginary(x,y) is calculated using the same simulation method, as shown in Figure 2, for real(x,y). Both real(x,y) and imaginary(x,y) in Equation (1) are calculated for every combination of (x,y)s, 256x256 pairs when a gray level is coded as 8 bit.

Other measures proposed for the dynamic false contours [8-10] can be used instead of Equation (1). But, the measure in Equation (1) is employed in this paper for its computational simplicity. Another reason for choosing Equation (1) is that the proposed algorithm utilizes relative orders of the magnitude, and not the exact magnitude of the dynamic false contours.

2.2 Construction of gray level conversion LUT

Once the measure of the dynamic false contours, contour(x,y), is calculated for each of the 256×256 combinations, the content of the gray level conversion LUT, mapping(x,y), is chosen by the following Equation (2).

$$\text{mapping}(x,y) = \arg[\min_{\alpha}\{\text{contour}(x,\alpha)\}] \qquad (2)$$

where mapping(x,y) represents a new gray level to be substituted for the gray level y at the (n)th frame to reduce the dynamic false contours, when gray level at the (n-1)th frame was x. The region for search space α in Equation (2) is defined as

$$y - \text{contour}(x,y) \le \alpha \le y + \text{contour}(x,y) \qquad (3)$$

Equations (2) and (3) indicate that the mapping(x,y) is selected by searching the minimum value of the contour(x,y) in its neighborhood. Table 1 shows an example of selecting mapping(x,y) when x=63 and y=67. From the row marked as ★ in Table 1, it can be seen that contour(63,67)=8 and the minimum value of contour(x,y) in its neighborhood is 0 when x=63 and y=63. Thus, the gray level 63 is chosen for the pair of (63,67). It implies that the gray level 63 is displayed instead of 67 when gray levels of 63 and 67 are given at the (n-1)th and (n)th frame, respectively.

When there are multiple choices for the new gray level within the search space given in Equation (3), the new gray level is determined by the following procedures; For the gray levels yielding the minimum value of contour(x,y), distances (or differences) to the gray level of (n)th frame are determined. If the number of gray levels having the nearest distance is one, that gray level is chosen as the new gray level. If there are two nearest gray levels, one is selected randomly. In Table 1, when x=63 and y=60, there are three gray levels 59, 61, and 62 in the search space yielding the minimum value of contour(x,y)=1. In this case, the new gray level is randomly selected to be 59 or 61.

2.3 Error diffusion algorithm with LUT

The off-line procedures to construct the gray level

TABLE 1. An example of gray level conversion LUT.

Gray level pair		Degree of false contour	New level *Current frame*
Previous frame	Current frame		
...			
63	54	2	53
63	55	2	55
63	56	3	59
63	57	2	59
63	58	2	59
63	59	1	59
63	60	2	61
63	61	1	61
63	62	1	63
63	63	0	63
63	64	8	63
63	65	8	63
63	66	7	63
★ 63	67	8	63
63	68	7	63
63	69	6	63
63	70	6	76
63	71	5	76
63	72	7	79
...			

conversion LUT have been described. How the proposed algorithm is applied for displaying moving images on PDP will be described next. It is assumed that two consecutive frames are stored in memory. Based on the gray level conversion LUT and gray level combination at the (n-1)th and (n)th frame, the gray level of current frame is modified to reduce the dynamic false contours. This fact implies that the gray levels would not be exactly reproduced on PDP. For example, suppose that there is an image whose left half has constant gray 63 and right half shows constant gray 67. When it moves from right to left, the gray level combination at the border would be x=63 and y=67. As explained earlier, the gray level 63 would be displayed instead of 67, based on the gray level conversion LUT. If there is no additional processing, the border between the gray levels 63 and 67 would not appear on PDP.

In order to alleviate this problem, an error diffusion algorithm is applied. By the error diffusion, the differences between the original and modified gray levels are diffused into the neighboring pixels to be processed. In the above example, the difference between 63 and 67 is diffused into the pixels to be processed. Thus, the average gray levels are preserved on PDP.

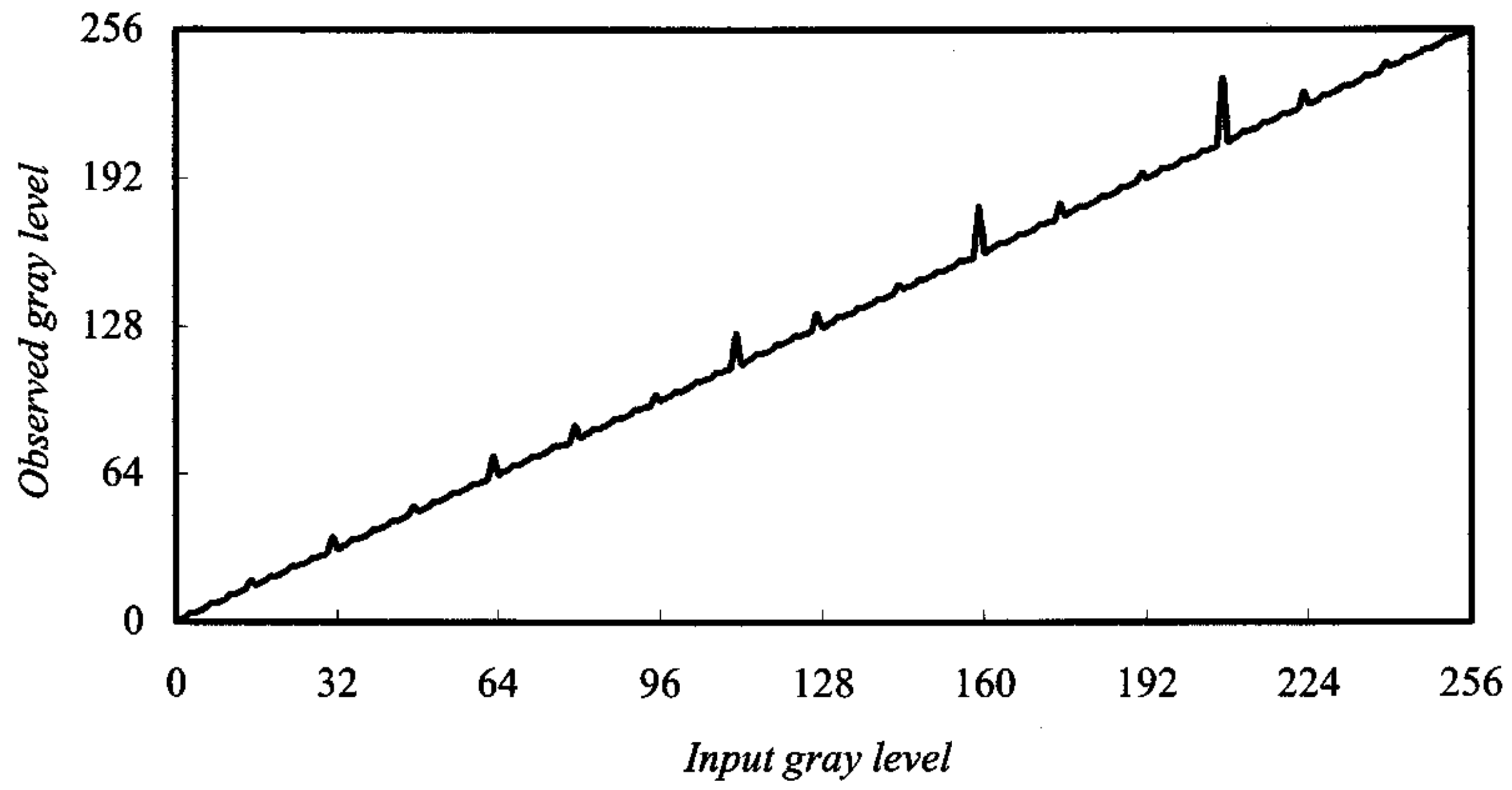
The error diffusion algorithm in this paper can be summarized as follows.

$$u_{i,j} = y_{i,j} + \sum_{k,l \in R} w_{k,l} e_{i-k,j-l} \tag{4}$$

$$b_{i,j} = LUT(x_{i,j}, u_{i,j}) \tag{5}$$

$$e_{i,j} = u_{i,j} - b_{i,j} \tag{6}$$

where $x_{i,j}$ and $y_{i,j}$ represent the gray levels of the (n-1)th and (n)th frame at the (i, j)th pixel location, respectively. In Equation (4), $u_{i,j}$ denotes the updated



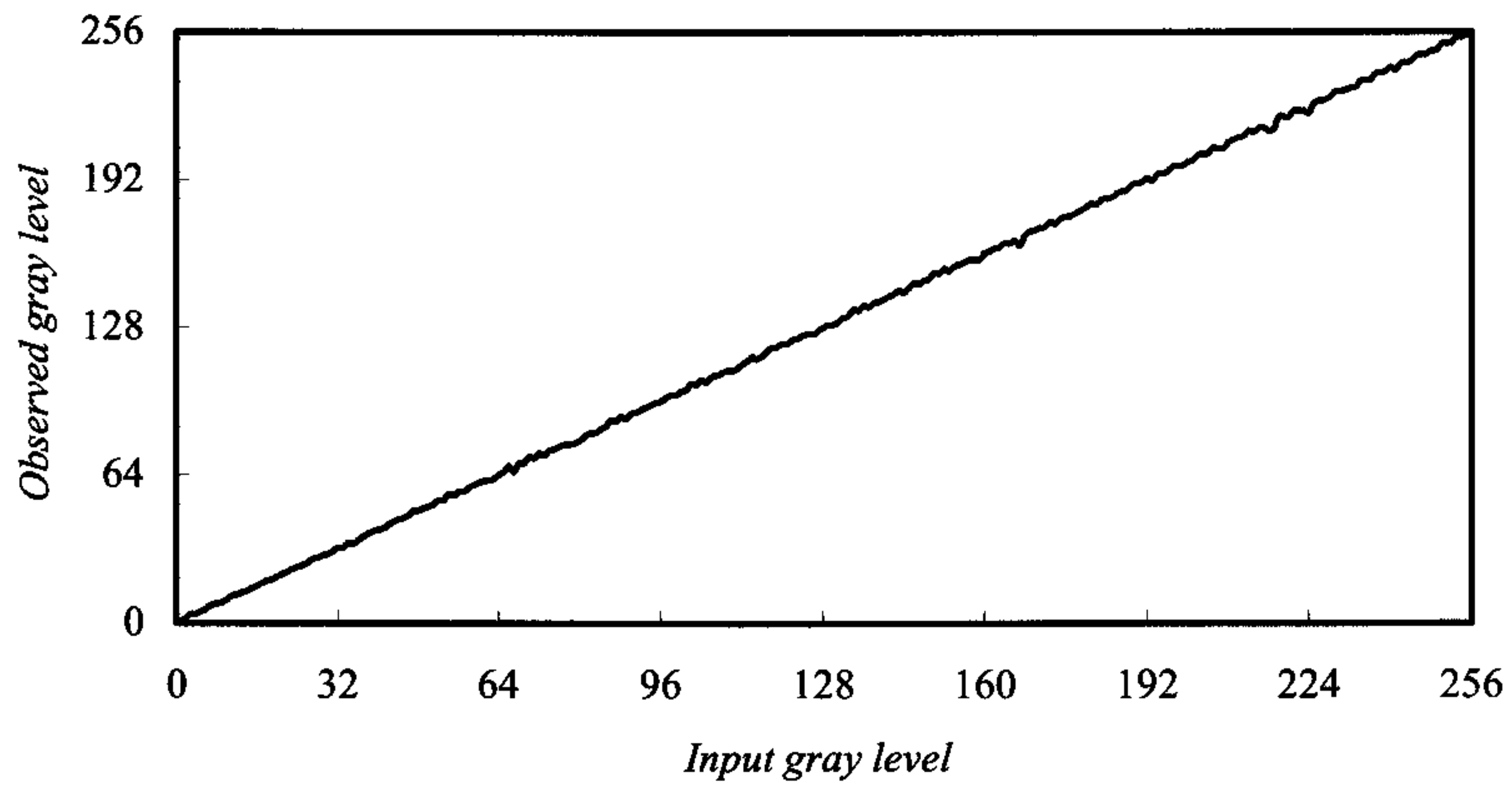


Fig. 5. Simulation results for gray ramp image (a) without proposed algorithm and (b) with proposed algorithm.

gray levels after error propagation. In Equation (5), $b_{i,j}$ is the new gray level at the (n)th frame determined based on the gray level conversion LUT. Also, In Equation (6), $e_{i,j}$ represents error due to the modification. It is weighted and diffused into the neighboring pixels defined by a set R. In Equation (4), $w_{k,l}$ denotes the weighting factor. Figure 4 shows the block diagram of the proposed algorithm.

3. Experimental Results

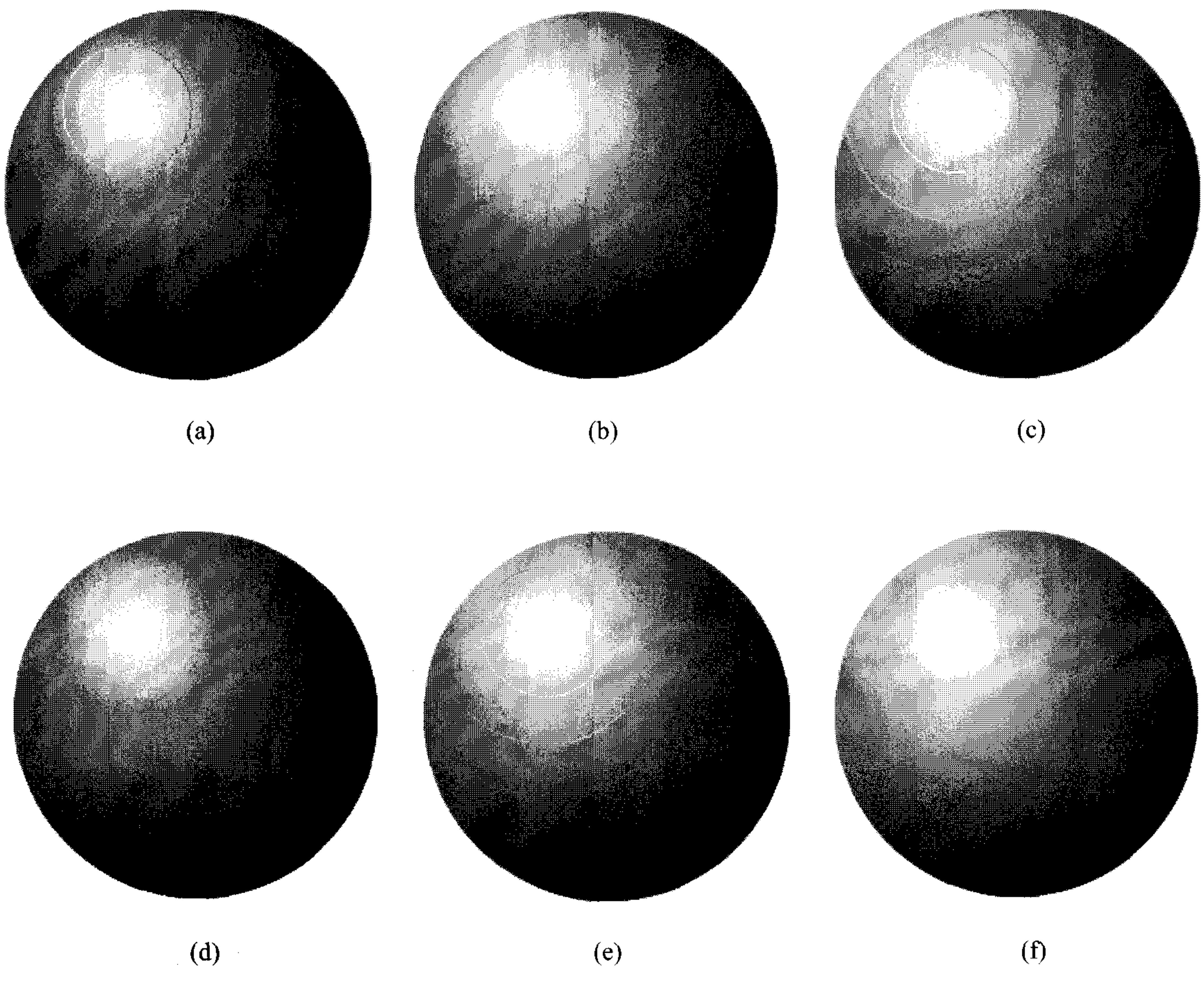
In order to examine the performance of the proposed algorithm, several experiments have been performed. The subfield pattern used in the experiments is [1 2 4 8 16 32 48 48 48 48]. Floyd-Steinberg error diffusion kernel [11] is utilized for the weighting factor, $w_{k,l}$, in Equation (4).

Figure 5 shows the simulation results for a gray ramp image. The horizontal and vertical axes in Figure 5 represent the gray levels of the ramp image and simulation results, respectively. It is assumed that the ramp image is moved from left to right at a speed of 1 pixel/frame. Figures 5(a) and (b) show the simulation results without and with the proposed algorithm, respectively. The several peaks shown in Figure 5(a) represent the dynamic false contours. They are reduced considerably as shown in Figure 5(b) where the proposed algorithm is applied.

Figure 6 shows the results for a real image. Figure 6(a) shows an original image. Figures 6(b) and (c) show the results without and with the proposed algorithm, respectively. For visibility, the simulation results are processed; The difference between the original and simulated images is taken and then thresholded. Most of the false contours in Figure 6(b) are hardly visible in Figure 6(c).

(a) (b) (c)

Fig. 6. Simulation results for real image (a) original image, (b) without proposed algorithm and (c) with proposed algorithm.



(a) (b) (c)

(d) (e) (f)

Fig. 7. Simulation results for gray sphere image (a) without proposed algorithm (0°), (b) with proposed algorithm (0°), (c) without proposed algorithm (45°), (d) with proposed algorithm (45°), (e) without proposed algorithm (90°) and (f) with proposed algorithm (90°).

Figure 7 shows the simulation results for a gray sphere image. Results on three different directions of motions are shown in Figure 7. Experimental results indicate that the proposed algorithm could reduce the dynamic false contours caused by the motions at different directions.

4. Discussions

The magnitude or degree of dynamic false contours depends on the speed and direction of motion. When an equalizing pulse technique is employed, the magnitude of dynamic false contour is directly utilized to determine the magnitude of equalizing pulse. Thus, the exact amounts and signs (+ or -) of dynamic false contours are of great importance for the equalizing pulse technique.

Ideally, different gray level conversion LUTs should be designed to accommodate the various speeds and directions of motion. However, in this paper, only a single gray level conversion LUT is selected among various LUTs designed, in advance, for different speeds and directions of motion. The selection is made based on the human visual tests on PDP.

The reasons for employing a single LUT can be explained as follows; First, it reduces memory space for storing the LUT. Also, it does not require priori information on motion that is computationally expensive. Second, it is based on the fact that the relative order of magnitude within a predefined search space is utilized to construct the gray level conversion LUT. The speed of motions would mainly change the magnitude of dynamic false contours. But, it might be assumed that the change in speed would not drastically affect the relative order of magnitudes.

The proposed algorithm can be utilized for color images. It can be applied to each of RGB channels independently. The proposed algorithm can be divided into three major components for hardware implementation ; (1) searching and fetching from the gray level conversion LUT, (2) storing of the gray level conversion LUT and (3) error diffusion technique. Among these three components, searching and fetching from the LUT would not take complex computations. The proposed size of the gray level conversion LUT is 256x256. But, the gray level pair having large differences would not yield the dynamic false contours. Thus, the size of LUT might be reduced for hardware implementation. For implementing error diffusion process as FPGA, it is expected that the clock speed of 28MHz and the number of gates of about 50,000 would be sufficient.

5. Conclusions

In this paper, a new LUT(Look-up table) based error diffusion algorithm is proposed for the reduction of the dynamic false contours. A simple quantitative measure of the dynamic false contours and an imaginary subfield pattern are defined to construct the gray level conversion LUT. Given a pair of gray levels of two consecutive frames, the gray level of current frame is modified based on the gray level conversion LUT. The new gray level is displayed on PDP. An error diffusion algorithm is then applied to compensate for the differences in the gray levels. Experimental results indicate that the proposed algorithm reduces the dynamic false contours without priori information on motions.

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