Digital Halftoning Algorithm Characterized by the Merits of FM and AM Screening Method

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Abstract

Algorithms of converting a continuous-tone image into a binary, high quality image has been studied in non-impact printing field. In this research we propose some idea to take advantage of both FM and AM screening method.

Introduction

Converting a continuous-tone image into a binary, high quality image is very important in non-impact printing field. A great number of digital halftoning algorithms have been presented. Recently, FM screening has been extensively studied. One of the disadvantages of FM screening is that the recording dots tend to form an objectionable cluster in the region with a certain range of optical density. In order to solve this problem, we propose to combine the conventional halftone screening process, or AM screening process, with FM screening process. Here we use the error diffusion method as FM screening method, and the halftone method as AM screening method. The input image is assumed to have 256 continuous tone value.

In the following the error diffusion process is explained: Let I(x,y) and O(x,y) denote the input and output brightness at pixel (x,y) respectively. The error created as a result of the pixel binarization is distributed with a certain ratio. The distributed error to adjacent pixel is summed with the current pixel brightness for determining the output value. In the conventional error diffusion algorithm, the modified input pixel brightness I'(x,y) is calculated from the input I(x,y) and the error of adjacent pixels. For a pixel at (x,y), the modified brightness I'(x,y), the output brightness O(x,y), and the error value E(x,y) are expressed by the following equations[1]:

$$I'(x,y) = I(x,y) + \frac{\sum_{i,j} a_{i,j} E(x+i,y+j)}{\sum_{i,j} a_{i,j}}. \qquad (1)$$

where the set of coefficients $a_{i,j}$ is expressed as:

$$\begin{bmatrix} - & * & a_{1,0} \\ a_{-1,1} & a_{0,1} & a_{1,1} \end{bmatrix} = \begin{bmatrix} - & * & 7 \\ 3 & 5 & 1 \end{bmatrix}. \qquad (2)$$

$$O(x,y) = \begin{cases} 0, & \text{if } I'(x,y) < 128; \\ 255, & \text{otherwise.} \end{cases} \qquad (3)$$

$$E(x,y) = I'(x,y) - O(x,y). \qquad (4)$$

In the following the halftone process is explained: Let I(x,y) and O(x,y) denote the input and output brightness at pixel (x,y) respectively. We use an 8 × 8 threshold matrix, in which the values of the center entries are higher than those of the entries around. Let $a_{i,j}$ ($1 \le i,j \le 8$) denotes an (i,j)-entry of this matrix. Then O(x,y) is expressed by the following equation:

$$O(x,y) = \begin{cases} 0, & \text{if } I(x,y) < a_{x \bmod 8,\, y \bmod 8}; \\ 255, & \text{otherwise.} \end{cases} \qquad (5)$$

The error diffusion method is effective especially to the image that requires a high quality simulation of continuous-tone appearance. On the other hand, the halftone method is effective to the image that requires a clear reproduction of brightness. In the following two sections we propose two algorithms. Algorithm (A) in the next section is a simple one in which the method to be used depends on the avarage density of the region. Algorithm (B) in the third section is basically an error diffusion algorithm with a threshold matrix introduced. These algorithms are motivated by considering the human characteristics about recognizing objects in a image.

In Figure 1(a) and 1(b), the output images are shown. The input image has 256 continuous brightness gradually decreases from the top line down to bottom.

Combination of Error Diffusion and Halftone Method

As we mentioned above, the halftone method has better reproductivity of brightness than the error diffusion method does. Naturally we think it effective to use both methods. The areas having high density, or low brightness, should be binarized by the halftone method, and low density by error diffusion method. We propose the following algorithm;

Algorithm (A):

1. Divide the original image into small square areas each of which has n by n dots.
2. Scan each small square area and calculate the average density $\bar{d}$ of pixels.
3. Compare $\bar{d}$ with the threshold value T for each small square area.
4. If $\bar{d} > T$, use the halftone method to binarize the area. Otherwise, use the error diffusion method.

We show an example of binarization by the algorithm (A) in Figure 2.

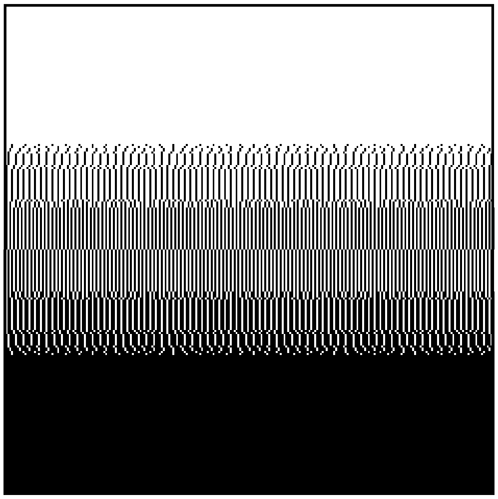

Figure 1(a). Error Diffusion

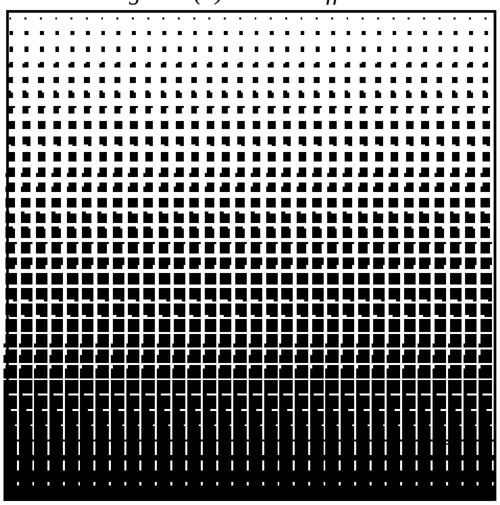

Figure 1(b). Halftone

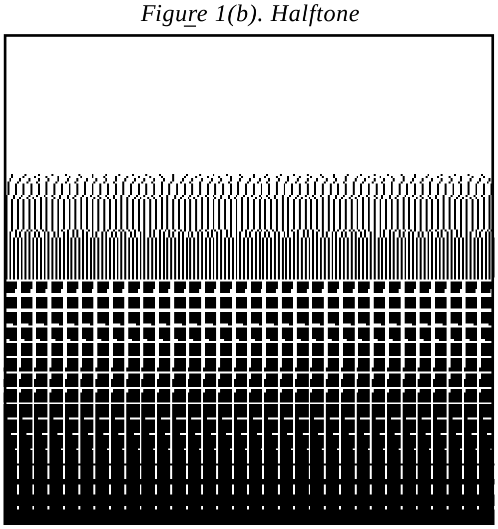

Figure 2. Combination (Algorithm (A))

For the algorithm (A) it is still unsolved to optimize the size of a small square area, that is, the value of n. It is also a problem on the algorithm (A) that there can be objectionable patterns at the boundary of two adjacent small square areas binarized by different methods in the output image. In case of general continuous-tone image, however, no distinct boundary like the center line in Figure 2 is expected to appear. To solve this problem we are now considering to change the shape of the boundary line at random.

Mixture of Error Diffusion and Halftone Method

In the algorithm (A) two methods are simply combined. In this section we propose to mix the two methods. We use the error diffusion algorithm with the threshold matrix. This algorithm comes from a human visual characteristic, that is, we are not so annoyed by the periodicity. We describe the algorithm (B) in the following;

Algorithm (B):

1. For each pixel, calculate the modified input pixel brightness I'(x,y) as mentioned in the explanation of the error diffusion method.
2. Compare I'(x,y) with the corresponding entry of the threshold matrix.

We show an example of binarization by the algorithm (B) in Figure 3. The value of entries of the threshold matrix we use here ranges from 96 to 159.

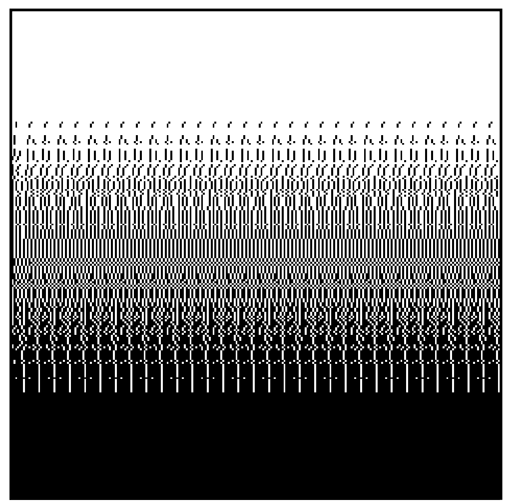

Figure 3. Mixture (Algorithm (B))

Summary

We propose two algorithms used for the binarization of continuous-tone images. It is still unsolved in both alogrithm to determine the optimal value of the threshold and the size of the matrix.

References

1. R. Floyd and L. Steinberg, An Adaptive Algorithm for Spatial Greyscale, *Proc. SID*, Vol **17**, No 2, pp. 75-77, 1976.

❋ Previously published in *IS&T's NIP 11*, 1995, pp. 473–474.