Halftoning Method by CMY Printing Using BNM

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Abstract

Digital halftoning is a technique to make an equivalent binary image from scanned photo or graphic images. Low pass filtering characteristic of human visual system can be applied to get the effect of spatial averaging of local area consisted of black and white pixels for gray image.

The overlapping of black dot decreases brightness and black dot is very sensitive to human visual system in the bright region. In this paper, for gray-level expression, only bright gray region in the color image is considered for blue noise mask (BNM) approach. To solve this problem, BNM with CMY dot is used for the bright region instead of black dot. Dot-on-dot model with single mask causes the problem making much black dot overlap, color distortion. Therefore approach with three masks for C, M and Y each is proposed to decrease pixel overlap and color distortion.

Keywords: *Digital Halftoning, Blue Noise Mask, CMY combination*

1. Introduction

Digital image halftoning is a technique to make an equivalent binary image from scanned photo or graphic images. Low pass filtering characteristic of human visual system can be applied to get the effect of spatial averaging of local area consisted of black and white pixels in case of gray image.

The techniques for digital halftoning include ordered dither, error diffusion, and BNM.

Ordered dither method uses predetermined threshold to get binary pixel value, and it is faster than other approaches. For the simple thresholding, regular pattern can be shown, and its performance will be degraded on the printer with low resolution. Error diffusion method diffuses the quantization error for center pixel into neighborhood pixels. The merits for this approach are clear boundary and good quality. But it has demerits as worm-like pattern in bright, dark region and with slow computation speed [1]-[3]. BNM approach consists of mask generation and thresholding. The mask has high frequency band in the frequency domain and threshold for each mask pixels. It is faster than above error diffusion and there is no worm-like pattern because of threshold operation. For the mask pattern, there can be unnatural patterns on the processed image [4]-[8]. To improve the BNM approach, MTF (Modulation Transfer Function) based on human visual characteristic or circular dot-overlap model is introduced for the design of mask [9]. Recently, this kind of gray level representation is extended to the field of color halftoning. If the mask for gray level expression is applied to three frames as C, M and Y respectively, colorimetric error would increase because there is no factor considering the relationship between color channels. To decrease the colorimetric error, vector error diffusion is introduced [10]. In this approach, error is propagated into neighborhood pixels in the form of vector like CIELab [11]. The reason for using CIELab space is to get uniform error metric in color space. But the complexity of computation is high because transform of RGB into CIELab is non-linear operation and artifacts like smear can be shown.

In this paper, gray and color modules are proposed as gray-level expression with BNM and design of three mask patterns for CMY.

For BNM approach with single mask, there is some dot overlap and this pattern causes color distortion. In this paper, approach with three mask for C, M and Y each is proposed to decrease dot overlap and color distortion. At first, mask for cyan frame is selected as BIPPSMA (binary pattern power spectrum manipulating algorithm) of Mitsa and Parker. The size of mask is 256x256 and mask for magenta can be obtained from rotating cyan mask by 90 degrees. In the same manner, mask for yellow can be obtained by selecting rotation angle as 180 degrees from cyan mask. This way can avoid pixel overlapping of color planes mutually. Therefore this reduces the misregistration of the color planes and a disturbing band effect which is represented in a previous dot-on-dot method [12].

Secondly, only bright gray region in the color image is considered for BNM approach. By using only black dot, the middle gray range can be well presented, but dark and bright region can't be represented well. For dark region, the overlapping of black dot decreases brightness and black dot in the bright region is very sensitive to human visual system. To solve this problem, BNM with CMY dot is used for the bright region rather than black dot.

2. Construction of BNM

BNM is two-dimensional mask making binary pattern to have blue noise characteristic. Blue noise has no low frequency, has a flat region in the high frequency region. In the BNM, the pixel of each mask has the threshold value. By pixel-by-pixel comparison, halftoned image is obtained.

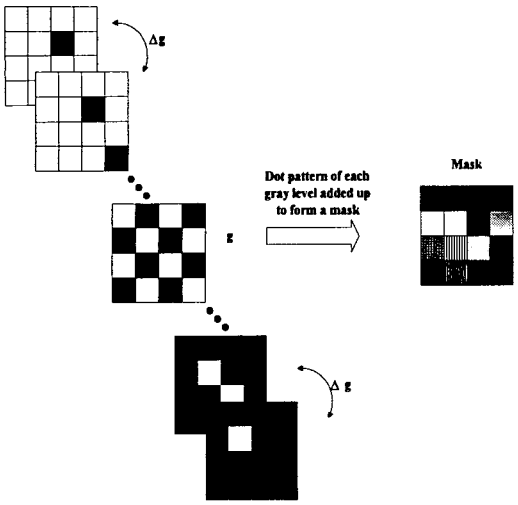


Fig.1. Construction of BNM using dot patterns.

At first, the dot pattern having a specific gray level (g) is constructed, Low Pass Filter is used to have binary pattern removing a periodic low frequency band. In the procedure of constructing mask, the pixel corresponding to the Δg's gray level is added or removed to make g+Δg's dot pattern from gray level g. In this way, the dot pattern corresponding to all gray level is constructed, 256 dot patterns is made in 8-bit gray level. In the each dot pattern, the pixel value is normalized (0 or 1), summed. Thus the mask has the all gray level's threshold value. This is faster than error diffusion and there is no worm-like pattern because of threshold operation. For the mask pattern, there can be unnatural patterns on the processed image.

In the proposed algorithm, BNM is constructed by the method using Mitsa and Parker's algorithm, has the 256×256 size [4].

3.1 Method for CMY combination

For gray-level expression, only bright and dark gray region in the color image is considered for BNM approach. By using only black dot, the middle gray range is well presented, but dark and bright region cannot be represented well. For dark region, the overlapping of black ink decreases brightness and black dot in the bright region is very sensitive to human visual system. To solve this problem, BNM with CMY dot is used for the bright region rather than black dot.

In the BNM approach, assume we have two continuous gray level to represent A and A'. To express A', the cross-relationship between A and A' is used while the value of A is preserved. By this relationship, if the input value to be printed is above 2/3 of whole dynamic range, the number of dots is multiplied by 3 compared to the number of dots for A'. The reason for take the threshold as 2/3 is as follows. To print one gray level in BNM, 256 dots are needed for

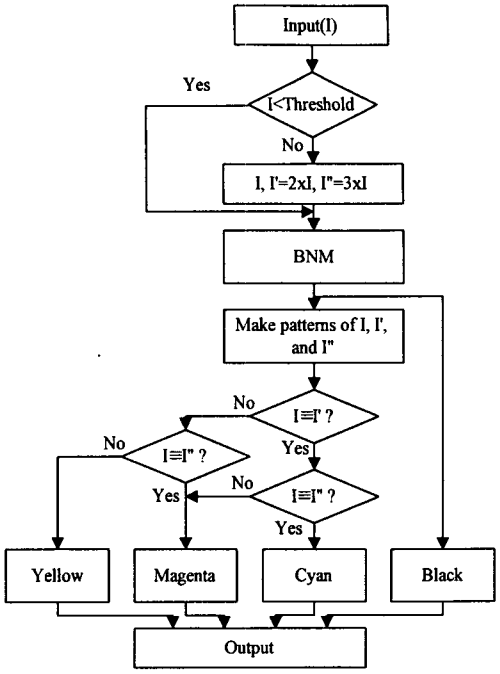


Fig.2. Block diagram of proposed algorithm.

256×256 size of mask. If the gray value under this threshold is printed by CMY combination, human don't notice artifacts. By coupling the above scheme with threshold of 2/3 and BNM, CMY dots can be printed uniformly for corresponding printed image.

Proposed algorithm is below. At first, threshold is decided to avoid pixel overlap. Below the threshold, BNM is processed, black dots is assigned. Above the threshold, we assign corresponding gray level into cyan, double of gray level into magenta, and three times of gray level into yellow. And we make CMY binary dot by using BNM. If all cyan, magenta, and yellow dots overlap, print cyan dot only. If magenta, yellow dots overlap, print magenta dot only. Finally, we obtained output image which is composed of black, cyan, magenta, and yellow pixels.

But using CMY combination instead of black dots has the problem, because practically printing of one black dot is darker than three dots of CMY which are dispersed. Thus tone rescaling is needed, discussed in the following section 3.2

3.2 Connection of tone curve

In this approach, threshold value is set to 2/3 of full dynamic range, for example, 255 and is very important for the performance. The size for BNM is 256x256 and to increase one gray level, 256 dots are needed. If the gray level is lower than 2/3 of 255, corresponding CMY dots begin to overlap. This CMY dot scheme is applied to upper 84 gray levels from 172 to 255. Black dot scheme is applied to other range from 0 to 171. This scheme has discontinuity between level 171 and 172 because of distortion in gray level. To avoid the discontinuity, 20 patches are printed in CMY for the range of 2/3 to 1 and measured in Lab coordinate value by spectrophotometer

(MinoltaCM3600d). And 64 patches for the range from 0 to 255 are printed in black dot. The gray difference between patches is 4. These patches also measured. From the analysis of these measurements, for the levels 2/3 and 1 are printed by CMY combination and other levels are printed by black dot.

In Fig.3, Lab value corresponding to dynamic range from 0 to 255 is evaluated using black dot, CMY dots are used from 172 to 255. In fig.4, because a high dark area is not noticeable, tone reproduction is needed. Therefore, gray levels from 0 to 171 in response to gray levels from 20 to 192 using black dots is used, in remaining dynamic range, gray levels from 172 to 255 using CMY dots is used. When black dots and CMY dots are combined, wider dynamic range can be available. And we can obtain more linear tone curve. If a highlight gray level is expressed with some black dots and white paper, granularity is increased. However CMY dots are used like proposed method in the highlight region, granularity is decreased, smoother, better quality image is obtained.

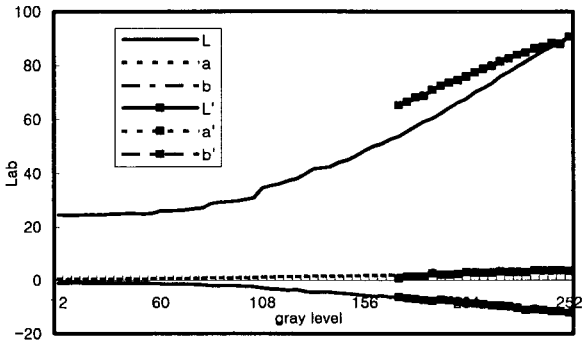


Fig.3. CIELab value using black and CMY dots.

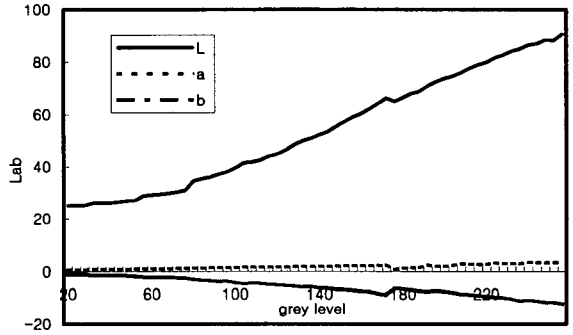


Fig.4. Connection of tone curve using black and CMY dots.

4. Modified BNM with rotation angle

If only single mask is used in BNM, the probability which the black dot will print increase in the same position. In the previous cluster dithering method, for example, rotated scheme used 30°, 45°, 75° rotations between each color plane mask. If this method is used, misregistration and moire pattern of color planes will be reduced, black dot will be less printable than conventional method.

In this paper, three masks scheme is that one BNM by BIPPSMA algorithm is constructed, this BNM is rotated in 90° totally, and then this repeatedly is rotated, third mask is obtained. With using this three BNM, each CMY channel is used as threshold mask. Fig. 5(a) shows BNM, Fig. 5(b) is the mask which is rotated by 90° with BNM, and Fig. 5(c) presents the mask which is rotated by 180° with BNM. Because of BNM property, each rotating mask has less pixel value of overlapping. Among these masks, the number of overlapping pixel are two hundreds pixel, the number is smaller than number of total pixel.

$$M_{cyan}(i,j) = \sum_{i=0}^{M}\sum_{j=0}^{N} BNM(i,j), \quad (1)$$

$$M_{magenta}(i,j) = \sum_{i=0}^{M}\sum_{j=0}^{N} M_{cyan}(j,i), \quad (2)$$

$$M_{yellow}(i,j) = \sum_{i=0}^{M}\sum_{j=0}^{N} M_{magenta}(j,i), \quad (3)$$

where i=1,...,M, and j=1,...,N.

M is the height of mask, N is the width of mask. BNM(i,j) is BNM by BIPPSMA, $M_{cyan}(i,j)$ is the mask assigning BNM(i,j), $M_{magenta}(i,j)$ is the mask making BNM(i,j) rotate by 90°, and $M_{yellow}(i,j)$is the mask making $M_{magenta}(i,j)$ rotate by 90°.

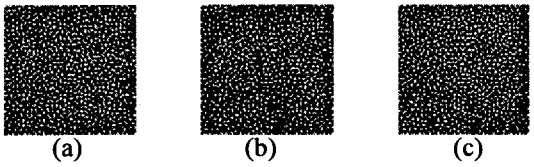
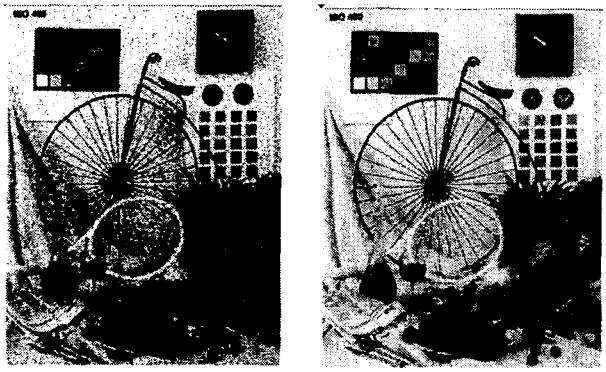


Fig.5. (a) BNM by BIPPSMA, (b) BNM by 90° rotation, (c) BNM by 180° rotation.

5. Experiments

In this paper, gray and color image are used. Fig.6 shows the result of CMY combination method, and Fig.7 shows the result of rotated scheme.

Fig.6 (a) is a bike gray image using BNM and Fig.6 (b) is a result image when the proposed CMY combination method is used. While BNM has the high granularity, narrow dynamic range, the CMY combination method has low granularity, wide dynamic range, high contrast properties. Because the proposed method uses three times dots than a conventional BNM, it expresses more spatial information while it has a similar gray level with BNM. Fig.7 (a) is Airplane image, and the proposed method shows better result than BNM method like Fig. 6. Fig.8 (a) is a bike color image using BNM and Fig.8 (b) is a result image used by the proposed the rotated method. The dot overlap is reduced remarkably, it presents the region of details. Fig. 9 shows the same result like Fig. 8.

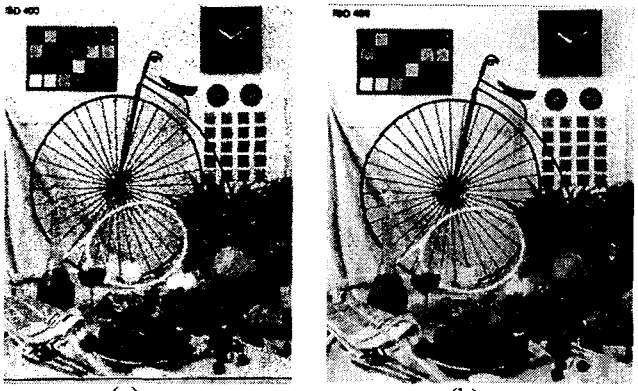


(a) (b)

Fig.6. Result for B/W Bike image (a) BNM, (b) CMY combination.

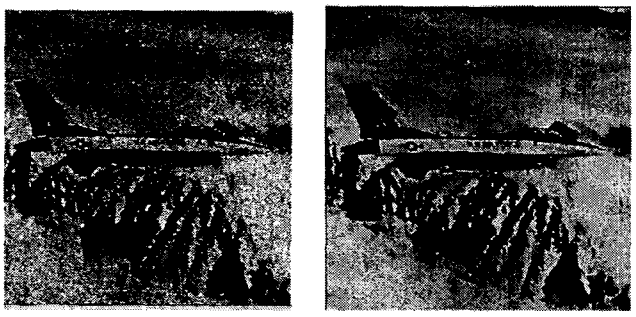
(a) (b)

Fig.7. Result for B/W Airplane image (a) BNM, (b) CMY combination.



(a) (b)

Fig.8. Result for Color Bike image (a) BNM, (b) rotation of three masks.



(a) (b)

Fig.9. Result for Color Airplane image (a) BNM, (b) rotation of three masks.

6. Conclusion

In the proposed CMY combination method, achromatic region for color image is printed well with less granular pattern and good quality and contrast compared to regular BNM approach. Approach with three mask for C, M and Y each is proposed to decrease dot overlap and color distortion. For the experiment, gray region of the processed image is uniform and bright sufficiently compared to conventional results with black dots. In color image, the processed image is more bright and uniform compared to conventional dot-on-dot scheme for each C, M and Y channel. Two proposed method has low granularity, wide dynamic range, high contrast properties.

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