The Eighteenth International Symposium on Artificial Life and Robotics 2013 (AROB 18th '13),
Daejeon Convention Center, Daejeon, Korea, January 30-February 1, 2013

Color Halftoning Using the Error Diffusion Method by the Edge Adjustment and the False Colored Limit

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Abstract: In the device that the usable number of the colors and density of printer or facsimile communication are limited, the digital halftoning is an important technique. When you use error diffusion method for mix of color and monochrome images, false color appear in monochrome parts. The images were evaluated using the Mean Squere Error. The image evaluation of MSE had rise. And so the evaluation with the monitor, a very good value was in this way provided. Full-color images grayscale is not contaminated and black and white images, images of the experimental results of different patterns, without compromising the quality of the original error diffusion method, we solve the problem.

Keywords: color halftoning, error diffusion method, grayscale

1 INTRODUCTION

Digital halftoning [1] includes many methods. For example, there are the applications of the combination optimization problem, dither method, the error diffusion method [2]. Error diffusion method is applied easy for color image halftoning, and has already been put to practical use.

However, as for the problems of the error diffusion method, a domain of the grayscale [3] is that a color unrelated at all occurred when the image in a part of the color image is processed though it is necessary for white and black to express a domain of the gray scale. In other words it means that a false color [4] occurred.

Among others, there is a problem that this processing scatters an error, some outline parts become dim. we suggested the new error diffusion method that we emphasized an edge, Contrast adjustment and limited a false color, to solve these two problems.

2 TECHNIQUE

We will show a method used in this experiment here.

2.1 The emphasis of the edge

The emphasis of the edge used a Gaussian [5] filter with unsharp mask on this occasion again.

The unsharp mask is a method to add the difference share with the original image after shading off an image once. When blur the image, equation (1) used a Gaussian filter using a Gaussian functions.

$$f(x,y) = \frac{1}{2\pi\sigma^2} exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right) \qquad (1)$$

σ of the Gaussian coefficient assumed it 1 then.

2.2 The adjustment of the contrast

The adjustment of the contrast adjusted the bright place becomes brighter, the dark place becomes darker with the sigmoid tone curve [6] called the highlight shadow to darken to apply to a variety of original images.

In this study is adjusting the contrast by Equation (2) to coordinate the contrast.

$$\text{Before processing} = 128 \times \left(\frac{After\ processing}{128}\right)^C \qquad (2)$$

This expression (2) supports only numerical value to 0-128 of the brightness before the processing. The subsequent brightness changes the degree of the increase rate symmetrically.

Not only a hue improves by doing contrast adjustment, but also the place that brightness is remarkable and is high or is low becomes easy to make a hit for the halftoning of the false color limit.

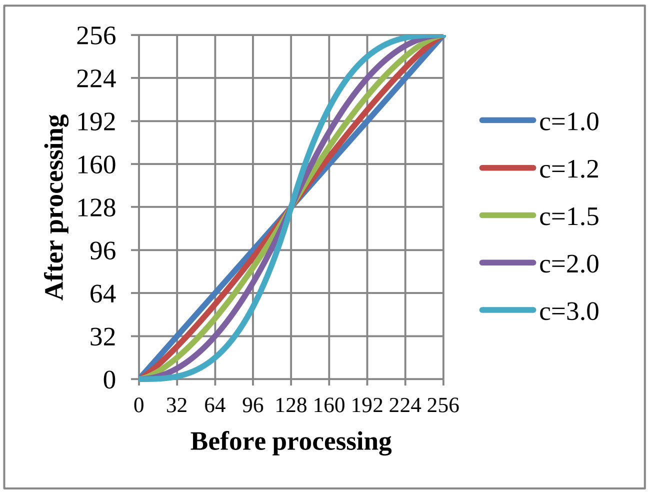


Fig. 1. The illustration of something

2.3 False color limit

2.3.1 Basic concept of error diffusion method

Fig.2 shows basic concept of the error diffusion me thod. Data f (n) is assumed that the value within the r ange of -1 ~ +1 is taken.

A. Data f (k) in n=k is read.Value g(k) ,which the qua ntization error is added, is given as follows,

$$g(k) = f(k) + e(k-1) \quad (3)$$

where, if k is equal to zero, quantization error $e(k-1)$ is equal to zero. This is because that n is greater that zero.

B. The values $g(k)$ are compared with threshold (=0) and binary number $H(k)$ is obtained as follows.

$$H(k) = \begin{cases} +1(g(k) \geq 0) \\ -1(g(k) < 0) \end{cases} \quad (4)$$

C. Quantization error $s(k)$ which generated between $g(k)$ and $H(k)$ is given as follows.

$$s(k) = g(k) - H(k) \quad (5)$$

D. Value $g(k+1)$, which the quantization error $e(k)$ i s added, given as follows.

$$g(k+1) = f(k+1) + e(k) \quad (6)$$

E. Ass data $\{f(n)\}$ are quantized by a similar process that consisting of the procedure 2~4, mentioned ab ove. Output binary number $\{H(n)\}$ is obtained.

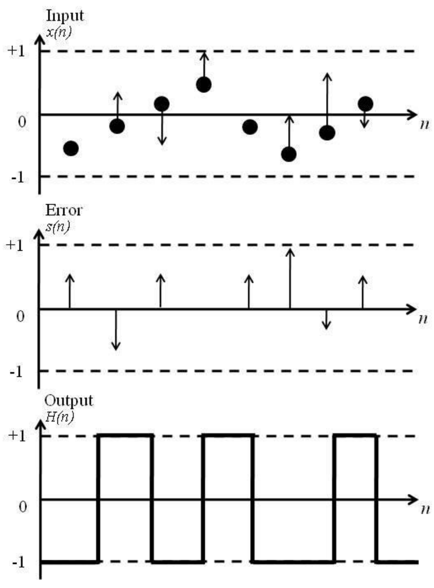


Fig. 2. Basic concept of error diffusion method

2.3.2 Extension to color image

The color image is composed by the combination o f each Red, Green, and Blue (three primary colors). At the color image the case of Windows Bit Map, the t hree primary colors of R, G and B has density inform ation of 0-255 respectively. Therefore, the color data is first divided into each primary color element. And, pr ocessing similar to the case of a monochrome image i s done. Each primary color results are united at the en d. Then, the color image can be treated.

In this study used error diffusivity of Floyd & Stei nberg which we showed in table 1. The pixels that sc attered an error by scattering an error in the pixel that does not perform threshold processing become easy to exceed the threshold. In addition, the scanning assume d it raster scanning.

Table 1. Floyd & Steinberg

g(-1,0)=0	g(0,0)=0	g(1,0)=7/16
g(-1,1)=3/16	g(0,1)=5/16	g(1,1)=1/16

2.3.3 New concept of error diffusion method

When the level of the original image color components R is equal to G, we keep that R is equal to G in the same position of the halftoning image. When the level of the original image color components R is equal to B, we keep that R is equal to B in the same position of the halftoning image. When the level of the original image color components B is equal to G, we keep that B is equal to G in the same position of the halftoning image. In case of a full-color image is constructed in grayscale, Halftone images should not be generated in colors that are quit irrelevant in black and white images.

Figure 3 shows relations of Red, Green, Blue, Cyan Magenta and Yellow.

Table 2 shows the list of the false color limit.

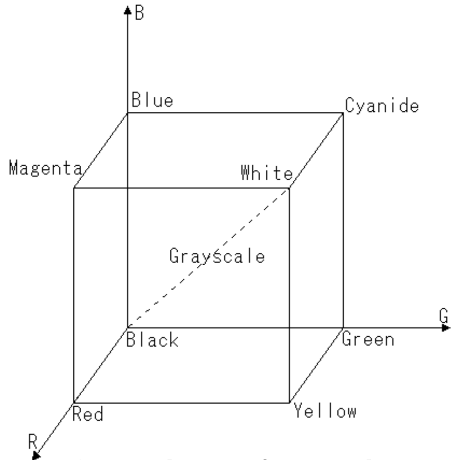


Fig. 3. Relations of RGB and CMY

Table 2. False color limit

Input data	The color that I can output	False color
R=G=B	White, Black	Red, Green, Blue, Cyanide, Magenta, Yellow
R=G	White, Black, Blue, Yellow	Red, Green, Cyanide, Magenta
R=B	White, Black, Green, Magenta	Red, Blue, Cyanide, Yellow
B=G	White, Black, Red, Cyanide	Green, Blue, Magenta, Yellow

2.4 Evaluation method

It is a picture evaluation of the halftoning about th e color image.

The valuation basis of a color image carries out co nvolution of the Gaussian filter to the RGB ingredient of the quantized image, and to create a pseudo-color image is represented. In this study, minimizing the me an squared Euclidean distance in RGB color space of t he image and the original image.

The MSE is defined as the equation (7).

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\{f'(i,j) - f(i,j)\}^2 \qquad (7)$$

In $f(i,j)$ in original image, $f'(i,j)$ decoding image, M and N show the size of the image.

It may be said that a high quality image was provided if a MSE level is small.

3 EXPERIMENTAL RESULT

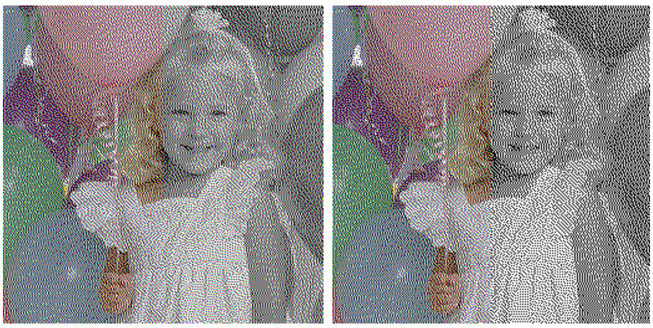
Comparing the processed image with conventional and suggestion method error diffusion method.

At first the right half compared it with an image of "Balloon" which became the grayscale. Fig 4 shows the results.

The left image of Fig 4 is the image which it processed by the conventional error diffusion method. The right image is the image which it processed by the error diffusion method of the proposed method.

Proposed method understands that a false color does not occur. The grayscale area is the error diffusion processing is not only black and white.

Table 3 shows an evaluation value for this image. 63 people were monitored. Good results were obtained with the monitor and MSE.

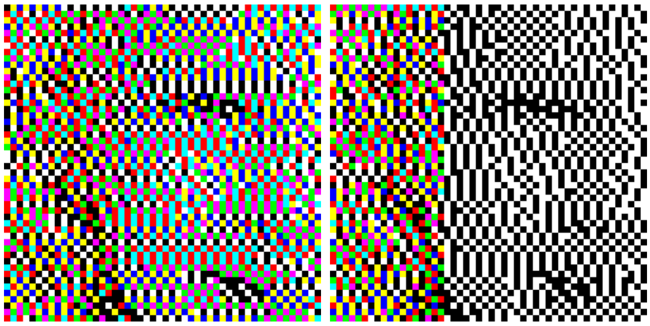


(a) Conventional method (b) Proposed method

Fig. 4. Comparison image of "Balloon" image

Table 3. "Grayscale Balloon" experimental results

	MSE	Monitor[people]
Conventional method	57.4170	1
Proposed method	56.1591	62



(a) Conventional method (b) Proposed method

Fig. 5. Enlargement of the right eye

Fig 5 shows an enlargement of the right eye of girl having Balloon in Fig 4.

In this study compare it with six kinds of original images "Aerial" "Airplane" "Balloon" "Earth" "Mandrill" "tulip". Table 4 shows an evaluation value for each image.

Good results were obtained with the monitor and MSE.

There were not many differences of the value of MSE. However, the difference of the number of people with the monitor was clearly.

Here is an example "Balloon" and "Mandrill" image shows the results.

Fig 6 shows the original image. Fig 7 shows an image subjected to unsharp mask and contrast adjustment. Fig 8 shows an image of the conventional error diffusion method. Fig 9 shows images of the proposed error diffusion method.

The left image "Balloon", the right image "Mandrill" images show.

Table 3. Experimental results

		MSE	Monitor [people]
Aerial	conventional method	232.1830	5
	proposed method	197.6562	58
Airplane	conventional method	227.3057	2
	proposed method	188.3521	61
Balloon	conventional method	57.4170	1
	proposed method	56.1591	62
Earth	conventional method	103.9658	7
	proposed method	94.1132	56
Mandrill	conventional method	382.2701	2
	proposed method	355.2142	61
Tulip	conventional method	420.8529	3
	proposed method	409.8079	60

(a) Ballon (b) Mandrill

Fig. 6. Original image

(a) Ballon (b) Mandrill

Fig. 7. Unsharp mask and contrast adjustment images

(a) Ballon (b) Mandrill

Fig. 8. The conventional error diffusion method

(a) Ballon (b) Mandrill

Fig. 9. The proposed error diffusion method

4 CONCLUSION

The advantages of unsharp mask

- It was improvement that "large part of the change in gradation blurred" is defect of error diffusion method.
- Easy to handle.

The advantages of contrast adjustment

- Easier to hit when you try to limit false color.
- An objective visual evaluation increase.

The advantages of false color limit

- False color is eliminated.
- An objective visual evaluation increase.
- The grayscale is expressed more beautifully.

Good images were provided visually by taking above-mentioned process.

In the future, we will try to do a thing as a variety of value. For example, there are Gaussian coefficients and contrast adjustment coefficients. We want to obtain a good image and more.

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