The three optimization methods of searching the effective combination dither matrix

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Abstract: In this paper, we proposed the dither matrix for color image with optimization methods. A dither method displays a grayscale picture that is expressed two colors. They are black and white values. Thereby, in a picture, although it is two values, in view of a distant view, it seems that there is a monochrome shade. I used three methods that are Genetic Algorithm (GA), Simulated Annealing (SA), and taboo searching (TS). The criterion of comparing data is cost E that is the evaluation value of reproduction of gray image. And it is addition of evaluated value of gray level and evaluated value of contrast.

Keywords: Dither method,GA,SA,TS.

1 INTRODUCTION

Dither method [1] is the methods used by digital halftoning. Nowadays, There are some popularly methods of dither matrix. Bayer dither, mesh dither, and so on. These methods are actually good on a viewpoint of image quality. However, there is difference of evaluation value for using different images. In addition, conventional methods, Bayer dither for example, are not really optimal combination on a viewpoint of combinational optimization problem.

In this paper, we proposed the dither matrix for color image with optimization methods. I used three methods that are Genetic Algorithm (GA) [2],[3],[4], Simulated Annealing(SA) [5], and taboo searching(TS) [6]. Processing procedure is follows,

(1) The color image is composed of eight bits respectively of red, green, blue, and becomes 24 bits in total. Therefore, the color image is dividing into a red element, a green element, a blue element.

(2) And, the divided each element is optimized severally.

(3) The optimized element is synthesized and the color halftoning image is made.

The criterion of comparing data is cost E that is the evaluation value of gray level. And it is addition of cost E_m and cost E_c. Individuals that have small cost E are prior carried over.

2 DITHER METHOD

Organized dither method, as shown in Fig.1. below, the original image dither matrix (or Dither pattern) called intentional noise $D(i;\ j)i;\ j\ =\ 0;\ 1;\ \ldots\ldots;N\text{-}1$ are added, and then quantized. Now, the original image is shown as $f(n_1, n_2)\ n_1,\ n_1 = 0, 1, \ldots\ldots, \mathrm{M}-1$ of M×M. The handling of Fig.2. is equivalent with choosing the threshold as expression (1).

$$f(n_1, n_2) = \begin{cases} 1 & f(n_1; n_2) \geq p \\ 0 & f(n_1; n_2) < p \end{cases} \quad (1)$$

But

$$i = n_1\ mod\ N \quad (2)$$

$$j = n_2\ mod\ N \quad (3)$$

In this case, it is the operation method, and A $mode\ B$ means the rest that divided, A in B.

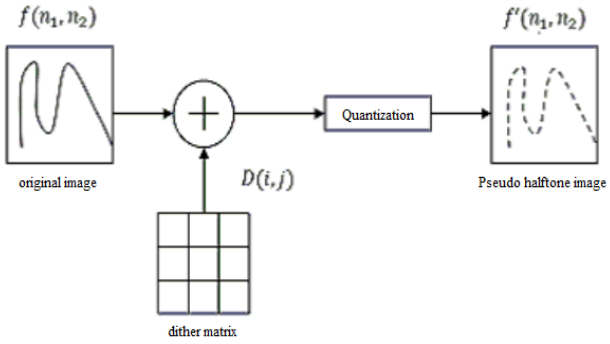

Fig. 1. Principle of the organized dither method

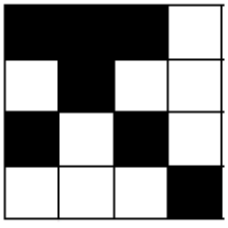

Fig. 2. Threshold change image

3 OPTIMIZATION METHODHOD

3.1 Genetic Algorithm

In this study, individuals are themselves. Elements of individuals are threshold level of gray level from 0 to 255. The threshold levels are Equation.1. "I[x]" is position x of the matrix. "i" is numerical number from 0 to 15. The numeral numbers of elements of Table 1 are "i" of equation (1).

The same number is not set in the same individual. GA is to convert grouping and to search what combination of elements is the optimal combination. In this study, the operation of GA which shows is as below.

(1) The matrices which have elements set in at random are prepared

(2) Set up solution of cost function E. Cost function E is the addition of cost E_m and cost E_c. Cost E_m is evaluated value of gray level. Cost E_c is Evaluated value of contrast. Equation of cost function E is as below.

(3) The individuals of next generation are decided by using the tournament method.

(4) Selecting two individuals and doing single point Crossover.

(5) Two elements of the individual which is selected at random are exchanged.

(6) Running over from (2) to (5) until the numbers of generations reach the generation number.

The number of individual is 200, the number of generation is 40, the probability of shakeout is 0.1 and the probability of mutation evolution is 0.01.

Single point Crossover is exchanging the position of elemental number from 0 to X of individual. The position of elemental number X is selected at random.

If the same elements are in the same individual, empty number of element sets one of duplicative element.

3.2 Simulated Annealing

In this paper, the algorithm of SA is as below.

(1) An individual that have matrices which is set elements in at random is prepared.

(2) New individual is made by changing element of the individual which is made at operation (1).

(3) Comparing two individuals

(4) New individual is made by exchanging element of the individual getting better evaluated value

(5) Running over from (3) to (4) until the satisfaction of the conditions.

In this study, the conditions are that temperature is under number which is set at hand or evaluated value of SA is better than Bayer method.

3.3 Taboo searching

The method of taboo searching is as below.

(1) The matrices which have elements set in at random are prepared (it is named individual A)
(2) Making some individuals based the individual A
(3) Evaluating and comparing these individuals
(4) The best evaluated value individual (it is named individual B) is selected by these individuals
(5) If combination of individual A and B has be selected before, return to operation (2)
(6) Comparing individual A and individual B
(7) If individual A is better than individual B, return to operation (2)
(8) If individual B is better than individual A, making some individuals based the individual B
(9) Running over from (3) to (8) until numbers of repeat time surpass numbers of generations

4 FLOW CHART

Figure 3 shows the steps from original image to halftone image.

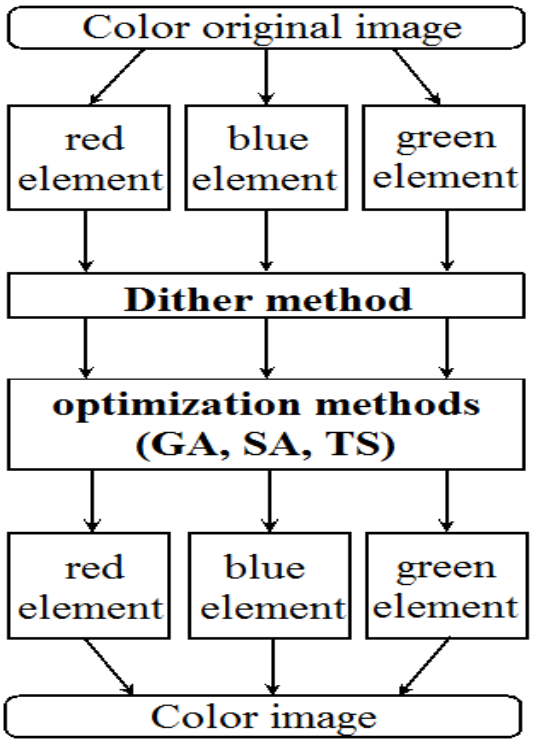

Fig. 3. Flow of optimized halftone image

5 EXPERIMENTAL RESULT

The following shows experimental results that was used this time. The picture is "Balloon" and "Mandrill" and "Parots" Using. In this study, I used the panmagic square dither because panmagic square dither was better than the bayer dither. Evaluation was performed by comparing the values of E. visually good Pseudo-gray image is given that by reducing the Evaluation value of contrast E_c and the Evaluation of the tone reproduction E_m. From the above, the evaluation value is represented by Expression (4).

$$E = \alpha_m E_m + \alpha_c E_c \quad (4)$$

An above expression's "α_m" and "α_c" are Weighting coefficients."α_m" and "α_c" is related to the following.

$$\alpha_m + \alpha_c = 1 \quad (5)$$

Changes in the tone reproduction and contrast of the image obtained according to the weighting coefficients.

Table 1. Experimental results using GA

Image name	E_m	E_c	E
Blue element "Balloon"	7.4926	127.6042	103.5820
Green element "Balloon"	6.5050	127.1885	103.0519
Red element "Balloon"	6.8001	127.2975	103.1981
Blue element "Mandrill"	16.5764	123.7008	102.2760
Green element "Mandrill"	16.2016	124.0656	102.4928
Red element "Mandrill"	13.8551	125.0254	102.7914
Blue element "Parrots"	8.5978	125.8586	102.4065
Green element "Parrots"	9.2138	126.0804	102.7071
Red element "Parrots"	8.5727	126.0877	102.5848

Table 2. Experimental results using SA

Image name	E_m	E_c	E
Blue element "Balloon"	6.9416	127.0003	102.9885
Green element "Balloon"	7.0533	127.2086	103.1775
Red element "Balloon"	6.8086	127.3100	103.2097
Blue element "Mandrill"	16.6493	123.7304	102.3142
Green element "Mandrill"	16.4153	123.7034	102.2458
Red element "Mandrill"	14.2207	125.1569	102.9696
Blue element "Parrots"	9.1002	125.8621	102.5097
Green element "Parrots"	8.6757	126.1537	102.6581
Red element "Parrots"	8.4334	126.0297	102.5104

Figure.4 shows the original image used in the experiment. The blue element of the original image was shown in Figure 5 and the green element of the original image was in Figure 6, the red element of the original image was in Figure 7. In addition, Figure 8 shows a synthesis of three elements. And Figure.9 shows an image using a panmagic square dither. Finally, Table 4 shows the evaluation of the best things in GA and SA and TS, which were compared with the panmagic square dither method's images.

Fig. 4. Original image

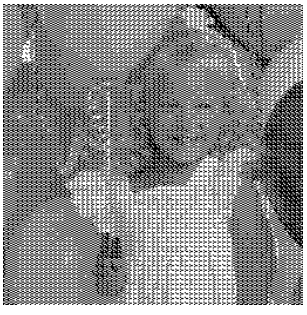

Fig. 5. Blue element

Table 3. Experimental results using TS

Image name	E_m	E_c	E
Blue element "Balloon"	9.0856	126.9960	103.4139
Green element "Balloon"	11.2213	127.2162	104.0172
Red element "Balloon"	8.7723	127.3087	103.6014
Blue element "Mandrill"	18.4120	123.9069	102.8079
Green element "Mandrill"	17.5246	124.0483	102.7435
Red element "Mandrill"	14.3682	125.1369	102.9832
Blue element "Parrots"	10.4983	125.8647	102.7915
Green element "Parrots"	11.6400	126.2159	103.3007
Red element "Parrots"	10.7327	126.1812	103.0915

Fig. 6. Green element

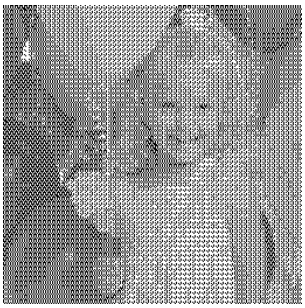

Fig. 7. Red element

Fig. 8. Synthetic image

Fig. 9. panmagic image

Table 4. Comparison of evaluation values about each element in "Balloon"

	Blue element	Green element	Red element
panmagic square dither	103.3915	103.5731	103.3127
The optimized value	102.9885	103.0519	103.1981

4 CONCLUSION

By using optimization techniques, in this study, obtained more good evaluation value than the conventional evaluation. Then, in the three methods, considering both calculation time and the evaluation value, we think that SA is the most good in the three methods. Because SA spent the shortest time in three method as the calculation and got good evaluation values on the average. Then, we obtained some opinions that this technique has better than conventional method in visually. In the future we would like to strive to improve the assessment by changing the input values during optimization. In addition, We would like to shorten the time of optimization about GA,SA and TS.

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