Contrast Improvement Using Genetic Algorithms by Region Segmentation

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ABSTRACT

This paper proposes a contrast improvement method that divides an image into several blocks and finds the optimum LUT for each block by Genetic Algorithms(GA). Experimental results show that the proposed method is effective in improving visually natural contrast.

1 Introduction

Today, the spread of smartphones has made it easier for us to take pictures. However, it is not always possible to take a picture with good contrast. One of the characteristics of grayscale images with good contrast is that the difference between light and dark is clear. Furthermore, it is known in research that if the edges of an object in an image are clear, the contrast is visually better[2]. Therefore, it is necessary to search for a LUT that is a table assigned from the input luminance value to the output luminance value according to the characteristics of the input image.

This paper proposes a method that divides an image into several blocks and then uses GA[1] with two fitness to search for a LUT to convert the image into optimum luminance values. Two fitness are the edge strength and the difference of average luminance value ratio in each block.

2 Proposed method

2.1 Region segmentation

The image is divided into 6 blocks, 2 vertical and 3 horizontal. The reason is that if the number of divisions is small, the amount of information in one block and the entire image does not change much, and if the number of divisions is large, over-emphasis may occur[3].

2.2 How to represent the LUT

Chromosomes are represented by a one-dimensional binary array, and the length is the luminance dynamic range of each block in the input image. By adding each bit of the chromosome in order, a monotonous non-decreasing curve is created. This curve is used as a LUT showing the relationship between the input luminance value and the output luminance value. To prevent the contrast from becoming unnaturally high, the maximum output luminance value of each block is determined by the ratio of the luminance dynamic range for each block the input image.

2.3 Fitness evaluation

In this paper, GA has two fitness. The first fitness is the average edge strength of one pixel compared with the entire image. As a preprocessing, edge detection is performed on the input image by the equations (1) and (2). The filter uses a noise-resistant Sobel filter[4].

$$f_x(x,y) = Y(x+1,y-1) + 2Y(x+1,y) + Y(x+1,y+1) - Y(x-1,y-1) - 2Y(x-1,y) - Y(x-1,y+1) \quad \cdots\cdots (1)$$

$$f_y(x,y) = Y(x-1,y+1) + 2Y(x,y+1) + Y(x+1,y+1) - Y(x-1,y-1) - 2Y(x,y-1) - Y(x+1,y-1) \quad \cdots\cdots (2)$$

Next, the edge strength $f(x,y)$ of the target pixel (x,y) is calculated by equation (3).

$$f(x,y) = \sqrt{f_x(x,y)^2 + f_y(x,y)^2} \quad \cdots\cdots (3)$$

Finally, the average edge strength E of one pixel is obtained by equation. (4).

$$E = \frac{\sum_x \sum_y f(x,y)}{n} \quad \cdots\cdots (4)$$

The second fitness is the difference of average luminance value ratio between the input image and the output image. First, we calculate $(A_I, B_I, C_I, D_I, E_I, F_I)$, which is the average luminance value ratio of each block in the input image compared to the average luminance value of the entire input image. Similarly, $(A_O, B_O, C_O, D_O, E_O, F_O)$ is calculated for the output image.

Next, A, which is the sum of the differences between the average luminance value ratios in the input image and the output image, is calculated by equation (6).

$$A = |A_O - A_I| + |B_O - B_I| + |C_O - C_I| + |D_O - D_I| + |E_O - E_I| + |F_O - F_I| \quad \cdots\cdots (5)$$

The final fitness F in this paper is evaluated by equation (6), which is the weighted addition of the edge strength E and the difference A of average luminance value ratio. The purpose of the weighting is to increase the edge strength of the image and to make the boundaries between the blocks less noticeable.

However, the second parameter in equation (6) is subtracted from the maximum value 2 that the difference of average luminance value ratio can take. The reason is that the larger the difference *A* of average luminance value ratio, the clearer the boundary between blocks.

$$F = \alpha * E + \beta * (2 - A) \quad \cdots\cdots (6)$$

3 Experiment

The experimental images were taken indoors or outdoors with insufficient luminance to confirm the effect of contrast improvement. The size of the image is 640×360 pixels and the maximum density gradation is 256. The GA operator has empirically set the numbers shown below. The number of individuals in one block is 30, the survival rate to the next generation is 50%, the mutation rate is 10%, and the coefficient (α, β) of equation (6) is (0.4,0.6).

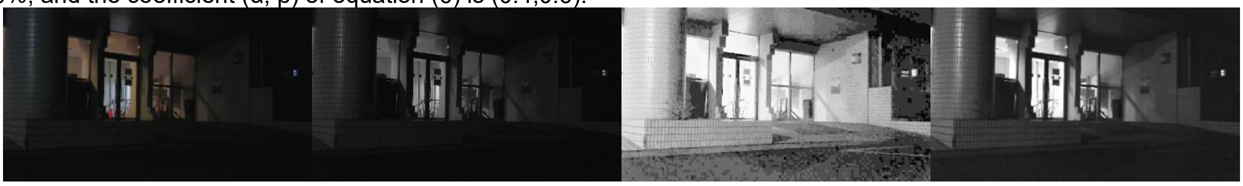
4 Result

4.1 PM result

Fig. 1 shows the original image and the result image of the contrast improvement by the two conventional methods and Proposed Method (PM). Conventional methods used Linear Gray-level Conversion(LGC) and Histogram Equalization (HE)[5]. From the left, the original image, LGC, HE, PM.

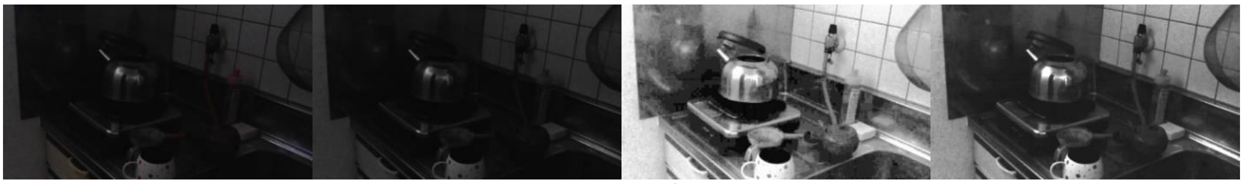
4.2 Subjective contrast evaluation

We conducted a subjective contrast evaluation showing the effect of PM using the four types of experimental images indicated in Fig. 1. First, the original image was displayed, and then three result images by

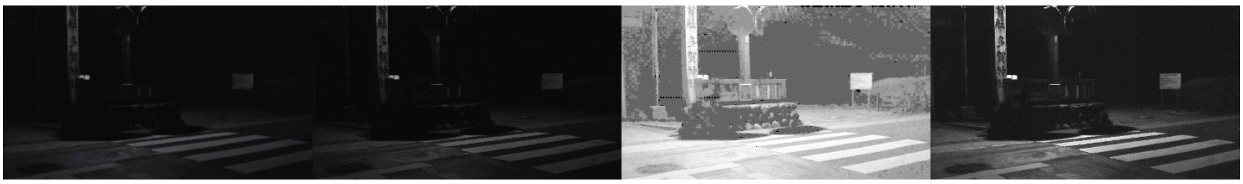


Picture A

Picture B



Picture C



Picture D

Fig. 1 Contrast improvement images (From left: Original image, LGC, HE, PM)

Table. 1 Experimental result of subjective contrast evaluation

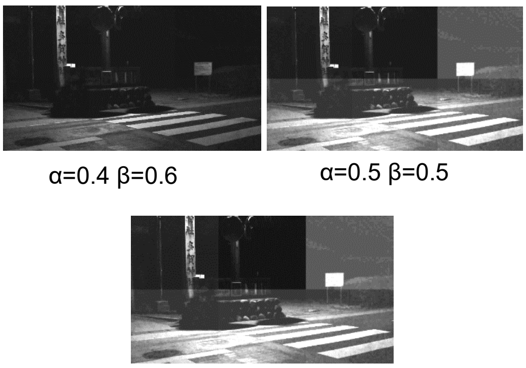
Methods	LGC				HE				PM			
Ranking	1	2	3	Averaged ranking	1	2	3	Averaged ranking	1	2	3	Averaged ranking
Picture A	1	6	3	2.20	0	3	7	2.70	9	1	0	1.10
Picture B	0	2	8	2.80	0	8	2	2.20	10	0	0	1.00
Picture C	0	3	7	2.70	2	5	3	2.10	8	2	0	1.20
Picture D	0	3	7	2.70	0	7	3	2.30	10	0	0	1.00
Total ranking	1	14	25	2.60	2	23	15	2.32	37	3	0	1.07

LGC, HE, and PM were displayed randomly. Next, we asked the subjects to rank the result images by paying attention to whether the result images have a visually clear and natural contrast compared with the original image and the absence of unwanted spots such as noise. The subjects are 10 students in their 20s.

Table 1 shows the number of subjects ranked from 1st to 3rd for each method and the average ranking. PM gave the best results in all the experimental images.

4.3 Weight coefficient in fitness evaluation formula

Fig.2 shows the effect of the weighting coefficients (α, β) in Equation 7 on the resulting image. The coefficient α is the weight of the edge strength, and the coefficient β is the weight of the average luminance ratio difference. When the value of α is large, the edges become clearer, while when the value of β is large, the boundaries between the blocks become less noticeable. Then, when five subjects selected the most natural result image, it was the case of (α, β) = (0.4, 0.6).



α=0.4 β=0.6 α=0.5 β=0.5

α=0.3 β=0.7

Fig. 2 Change of result image by weighting factor

5 Discussion

Since PM creates an optimum LUT for each block, it succeeded in improving the contrast of details compared with LGC, which extends the dynamic range linearly. Furthermore, since PM assigns the maximum luminance value of each block linearly, it succeeded in suppressing noise due to over-emphasis compared to HE.

6 Conclusions

We proposed a method to improve the contrast of the region segmentation image by using GA with the fitness of the edge strength and the difference of average luminance value ratio. Furthermore, we conducted a subjective contrast evaluation experiment using the result images of two conventional methods and the proposed method. As a result, it was shown that the proposed method obtains a visually natural and stable contrast-improved image as compared with two conventional method.

The use of new spatial features and optimization of the maximum output luminance value for each block are considered to be future issues.

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