Contrast Enhancement and Detailed Enhancement Method Based on Non-linear Filtering

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Abstract— **Smart phones with camera devices and media networks such as the internet and have been widely used, and images are used on SNS (Social Network Security). There are a lot of images which have low contrast. So, contrast enhancement, which is a technique to adjust brightness of images, is one of the important image processing technologies and is required. In this paper, we propose a contrast enhancement method based on non-linear filters. Experimental results show that reconstructed images are good contrast and image quality.**

Keywords—Contrast enhancement; Detailed enhancement; Total Variation Regularization

I. INTRODUCTION

The recent proliferation of smart phones with built-in cameras and digital cameras has contributed to the growing popularity of photography. However, there is undesirable quality degradation in many photographs, owing to various factors such as low contrast and backlight of camera.

To solve this problem, there are optical backlight correction functions in some digital cameras. However, these optical corrections are not sufficient in actual applications. Therefore, digital image restoration from one image is required by doing post-processing.

Contrast enhancement techniques can be broadly categorized into two methods: histogram equalization (HE) [1]–[2] and the Retinex method [3]–[4]. In general, the Retinex method produces more visually pleasing results compared with the HE method, especially for regional enhancement, which is impossible using HE-based methods.

In this study, a novel contrast enhancement technique is proposed where an image is divided into several blocks and an appropriate contrast-tone mapping curve is applied to each block. The aim is to obtain a similar level of performance as the Retinex method but with a much faster computational speed.

II. CONTRAST ENHANCEMENT

There are a number of contrast correction methods such as linear density conversion and non-linear density conversion. These methods analyze image histogram to process corrections. However, reconstructed images will have some degradation such as halo. To decrease halo, which appears in the conventional methods, we propose a novel contrast enhancement method which utilizes the Total Variation regularization [5]–[6], the Gamma correction and a detail enhancement method. Figure 2 shows a block diagram of the proposed method.

III. PROPOSED METHOD

In our proposed method, an input image is decomposed into a structure component and a texture component by utilizing the Total Variation (TV) regularization, and the structure and texture components are processed by utilizing a contrast enhancement and a detailed enhancement as shown in Fig. 1, respectively.

A. TV Regularization

The TV regularization is usually used for image decomposition into a structure component, which consists of smooth signals and edges, and a texture component, which consists of vibrating signals and noise, and the ROF model is realized to solve the minimization problem of an evaluation function $F(u)$ as shown in Eq. (1)

$$F(u) = \sum_{i,j}\left|\nabla u_{i,j}\right| + \lambda \sum_{i,j}\left|f_{i,j} - u_{i,j}\right|^2 \quad (1)$$

where f is an input image, u is the structure component, f-u is the texture component, and the right side first term is a TV term and the second term is a constraint term. It is possible to adjust amount of the texture component by changing the decomposition parameter λ.

B. Gamma Correction

The structure component is processed by utilizing Gamma correction as shown in Eq. (2)

$$X = x_{max}\left(\frac{x}{x_{max}}\right)^{\gamma} \quad (2)$$

where an input image is corrected to be brightly in γ<1, and it is corrected to be darkly in γ>1.

C. Detail enhancement

The property of our detail enhancement is not only to amplify the texture components but also to change enhancement ratio corresponding to those luminance. Weighted functions are shown in Eqs. (3) to (7)

$$Y(i) = V(i) \cdot (W_l(i) + W_m(i) + W_h(i)) \quad (3)$$

$$W_l(i) = \alpha_i \cdot (1 - U'(i)) \quad (4)$$

$$W_m(i) = \alpha_m \cdot \exp\left(-\frac{(U'(i)-\bar{U})^2}{0.04}\right) \quad (5)$$

$$W_h(i) = \alpha_h \cdot U'(i) \quad (6)$$

$$U'(i) = \frac{U(i)-U_{min}}{U_{max}-U_{min}} \quad (7)$$

where $U(i)$ and $V(i)$ are luminance of structure components and texture components, respectively, and α is a constant, which will control intensification degree, and the values U_{max} and U_{max} are a maximum and a minimum values at the structure component.

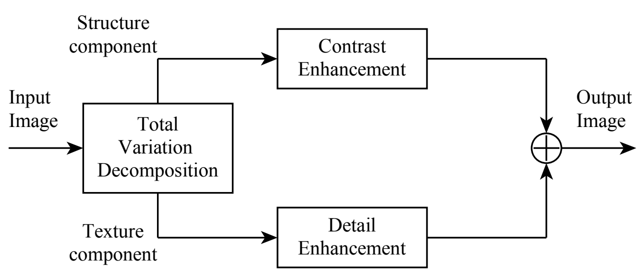


Fig. 1. Processing flow of proposed method.

IV. Experimental Results

We experiment using some images to validate the effectiveness of our proposed method. Tables I and II show the experimental parameters of the TV regularization and the detail enhancement in the proposed method, respectively. Figures 2 (a) and 3 (a) show the original images, which are 854 × 641 and 624 × 468 pixels, respectively. The block sizes were set to 1/4 of the original image, which generated 16 blocks in the regional DRSHE method [7]. The gamma value was set to 0.5 in the proposed method.

Table III shows the processing time for the Retinex method, the regional DRSHE method, and the proposed method. In this table, the computation time for the proposed method was considerably lesser than that for the Retinex method, and that for the proposed method is about twice for the DRSHE method, this is because it takes long time for iterative process of the TV regularization.

Figures 2 and 3, (b), (c), and (d) show the experimental results obtained by using the Retinex method, the regional DRSHE method, and the proposed method, respectively. The software of "Photo Flair" was utilized, which is one of the best implementations of the Retinex method.

In Figures 2 (c) and 3 (c), the regional contrast improvements are obtained, however, they are not sufficient for contrast enhancement. The results obtained with the proposed method have the most balanced image qualities, which are very similar to the results obtained using the Retinex method.

V. Conclusion

This study proposes a novel adaptive image contrast enhancement method where appropriate the TV regularization decomposition is applied to an input image using a simple process. The computational time required by the proposed method is less than that required by the Retinex method. Furthermore, the experimental results show that the method retains the characteristics of the input image as well as obtaining better regional image qualities than conventional methods. The proposed method can be implemented for consumer devices such as digital cameras and smartphones to improve the contrast of the images captured using these devices. For further research, we intend to implement our proposed method on FPGA to realize real time processing.

TABLE I. PARAMETERS OF TV REGULARIZATION.

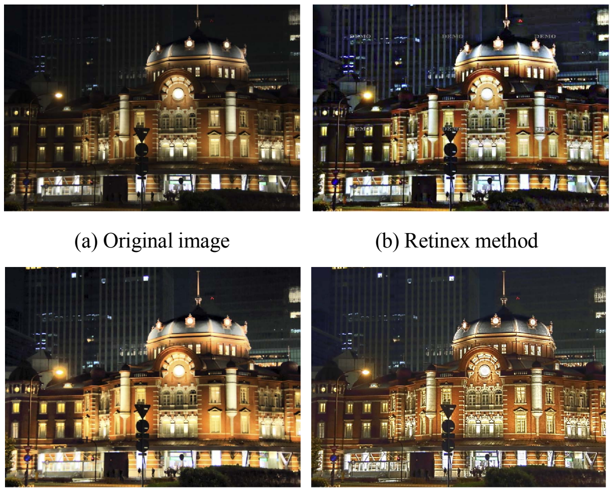
Parameter	Value
λ	0.04
Step size	0.125
Iteration number	10

TABLE II. PARAMETER OF DETAIL ENHANCEMENT FILTER.

Parameter	Value
α_l	5
α_m	1
α_h	1

TABLE III. COMPUTATIONAL TIME.

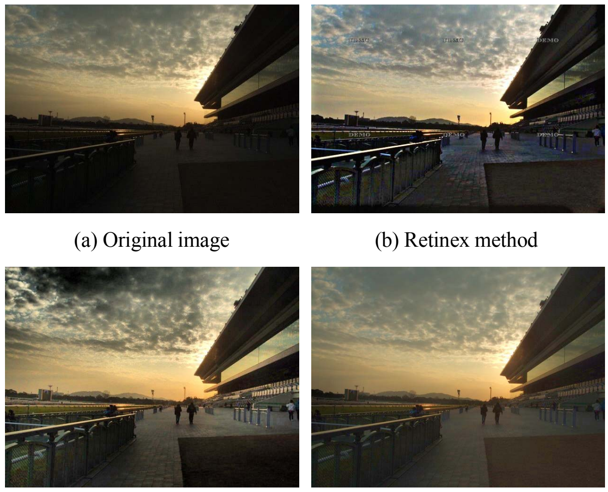
Method	Time [s]
Retinex [4]	1.30
Regional DRSHE [7]	0.16
Proposed method	0.34



(a) Original image (b) Retinex method

(c) Regional DRSHE method [7] (d) Proposed method

Fig. 2. Original image and reconstructed images (Tokyo station image).



(a) Original image (b) Retinex method

(c) Regional DRSHE method [7] (d) Proposed method

Fig. 3. Original image and reconstructed images (Racecourse image)

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