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Global brightness and local contrast adaptive enhancement for low illumination color image

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ABSTRACT

An adaptive enhancement algorithm is proposed in the paper for low illumination color image which is low brightness and low contrast. The algorithm is realized through three steps: the global brightness adaptive adjustment, locally adaptive contrast enhancement and color restore. Experiments show that the brightness and local contrast of low illumination color image can be effectively enhanced. The details, especially in the dark region of enhanced image are more prominent and the enhanced image is more vivid than some other methods for low illumination color image enhancement.

1. Introduction

Low brightness and low contrast images are often get in image acquisition and they are required to process for certain applications. At present, there are many image enhancement algorithms. From application purposes, these algorithms are used for denoising or enhancing brightness and contrast, and from process object, they are mostly used to process ideal light grayscale image. Low illumination color image enhancement research is a hot issue in recent years. The purposes for enhancement low illumination image are denoising, enhancement brightness and contrast; meanwhile color information also should be maintained. In brief, the purposes are to make low illumination color images brighter and more natural.

At present, low illumination color image enhancement methods there are methods based on color space conversion [1], Retinex and its improved algorithms [2,7–12], etc. Method based on color space conversion usually is used to transform original RGB image to a specific color space, then use the traditional gray image enhancement algorithm directly on the luminance component, and then transformed back to the RGB space to achieve enhancement task, but this kind of method is easy to cause the color distortion because of each color component processing is not consistent. Retinex and its improved algorithms are based on color invariant features, and their emphasis is focused on how to effectively estimate weight of background illumination. Retinex and its improved algorithms subtract the background illumination component directly from the original image in logarithmic space to realize overall image contrast enhancement, but local details did not improve. According to the global and local adaptive adjustment principle of human visual perception system, Literature [3] put forward a bionic color image enhancement method which has obtained the certain effect for non-uniform illumination image, but this method lead to reduce the image contrast because of compression image dynamic range with nonlinear power function for low illumination color image brightness enhancement.

HSV (Hue, Saturation, Value) color model was put forward by Munsel in 1939. HSV color model is used to process low illumination color image in the paper because it has a significant advantage: V component has nothing to do with the image color information and the processed image can keep the original image chroma. In fact, the image corresponding to V component is grayscale image that we are very familiar.

In this paper, the OBLCAE (Overall Brightness and Local Contrast Adaptive Enhancement, OBLCAE) algorithm based on HSV color space is proposed for low illumination color image enhancement. OBLCAE algorithm mainly includes three steps: the first is global brightness adaptive iterative adjustment; the second is adaptive

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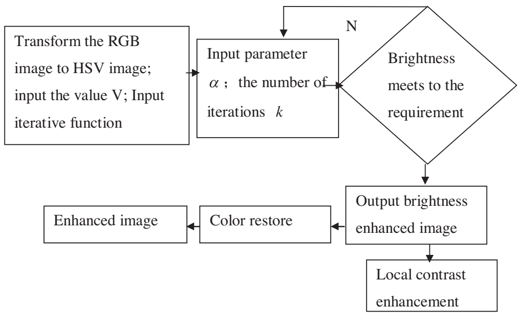

Fig. 1. OBLCAE algorithm flow chart.

local contrast enhancement and the last is color restoration. Our experiments show that the proposed method can not only adaptively enhance global brightness but also adaptively enhance local contrast and make the enhanced image details more clear and vivid.

The rest of this paper is organized as follows. Section 2 devotes to the details of the OBLCAE algorithm. Section 3 presents the implementation of our experiments and reports the results. Conclusions are given in Section 4.

2. The OBLCAE algorithm

In order to a better understanding of our algorithm, the flow chart of algorithm is shown in (Fig. 1):

The following three sections are devote to the details of the OBLCAE method.

2.1. Global brightness adaptive enhancement

Because of most of the color image is RGB color images, we first use transformation Eq. (1) to get V component value of HSV color model. The transformation Eq. (2) is used to get H component value of HSV color model.

$$V = \frac{1}{\sqrt{3}}(R+G+B) \tag{1}$$

$$H = \begin{cases} \theta, & G \geq B \\ 2\pi - \theta, & G < B \end{cases} \tag{2}$$

where R, G, B denote three components value respectively of RGB image, and θ is given by Eq. (3).

$$\theta = \arccos \frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}} \tag{3}$$

Eq. (3) indicates H component value will not change when R, G and B color component are transformed with same proportion. The key of implement low illumination image brightness overall enhancement in mathematics is how to set an appropriate monotone increasing convex nonlinear mapping function $y = f(x)$ which meets the constraint conditions $y = f(x) \geq x$ and $0 \leq f(x) \leq 1$, $x \in [0,1]$. where x denotes the normalized V component value of low illumination image pixels. Literature [3–5] designed respectively the following three luminance nonlinear mapping functions:

$$y = 1-(x-1)^2, \quad x \in [0,1] \tag{4}$$

$$y = x^{a/3+1/3}, \quad a \in [0,1], \quad x \in [0,1] \tag{5}$$

$$y = \sqrt{ax}, \quad a \in [0,1], \quad x \in [0,1] \tag{6}$$

It is pointed out in literature [13] that function (4) is better than the functions (5) and (6) for low illumination image enhancement, but function (4) there is no adjustment parameters and can

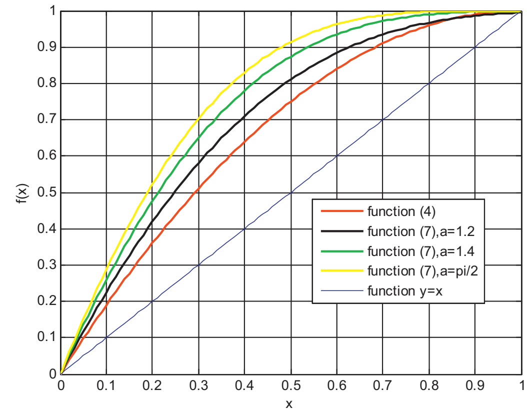

Fig. 2. Curves diagram of function (7) under different parameter values.

not adaptively adjust the brightness for different low illumination image. A new brightness mapping function (7) is designed in this paper.

$$y = 1-[1-\sin^2(ax)], \quad x \in [0,1], \quad a \in \left[1, \frac{\pi}{2}\right] \tag{7}$$

where α is adjust parameters. Composite function (7) is composed of a sine function and a parabolic function (4). Curves diagram of function (7) under different parameter values are shown in Fig. 2.

It can be seen form Fig. 2 that function (7) has a distinct advantage: brightness in dark area will not be enhanced too fast and brightness in light area will not be compressed too much according to adjust parameter α. Thus brightness adjustment ability is superior to the function (4), and enhanced image will be of good contrast. A simple method to determine adjust parameter α of function (7) is shown in the following Eq. (8):

$$a = \begin{cases} \pi/2, & L \leq 60 \\ 1.4, & 60 < L \leq 180 \\ 1.2, & L > 180 \end{cases} \tag{8}$$

where L ($0 \leq L \leq 255$) is the gray level that corresponds to the cumulative distribution function value equal to 0.3. That is to say, as 30% or more of the pixel gray level fall below 60, the image is very dark and parameter α is set to $\pi/2$, when 80% or more of the pixel gray level is greater than 180, we think the image is bright and parameter α is set to 1.2. In other cases, parameter α is set to 1.4. In view of the different brightness image, image brightness dynamic range can be adaptively adjusted through iterative calculation by the function (7) and will not overflow normal range which can cause hue distortion, so brightness adjusted image is more in line with human visual perception.

2.2. Locally adaptive contrast adaptive enhancement

Gray image local contrast CI is defined as Eq. (9).

$$\mathrm{CI} = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \tag{9}$$

where $I_{\max}$ and $I_{\min}$ represents respectively the maximum and minimum pixel gray value within the neighborhood. For RGB color images, the local contrast CI is defined as Eq. (10).

$$\mathrm{CI} = \frac{1}{3}(\mathrm{CI}_R + \mathrm{CI}_G + \mathrm{CI}_B) \tag{10}$$

where CI_R, CI_G and CI_B represent respectively three component local contrast calculated by Eq. (9). According to the human visual system characteristics, human visual is more sensitive to local contrast. For low illumination image, the local contrast enhancement is needed