Optimization of detailed information based on retinex algorithm for image enhancement

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Abstract

To solve the problem of poor processing of detailed information in image enhancement based on traditional Retinex algorithm, this paper proposes a kind of Retinex algorithm for image enhancement based on luminance block, which first introduces the background intensity to represent the stimulus intensity according to the Webb law in psychology, so as to segment the luminance block of image, and then use enhancement factors with different scales to enhance the segmented blocks; finally, after segmentation of the edge information of pixels, fuse the information of blocks in a way of proportion solution. Simulation results show that, the Retinex algorithm for image enhancement based on luminance block proposed by this paper has improved the information entropy than the original Retinex algorithm, and this method has a good effect in the application of image enhancement.

Keywords: Retinex algorithm, image enhancement, optimization of detailed information, luminance block, optimization of information entropy

1 Introduction

Image engineering is an interdisciplinary that systematically researches various image theory, technology and application, and its research method can learn from that of mathematics, physiology, electronics, computer science and other disciplines mutually, and the research scope intercrosses that of pattern recognition, computer vision, computer graphics and other profession [1]. According to the degree of abstraction and different research methods, from low to high, image engineering includes the three levels of image processing, image analysis and image understanding [2]. Image processing can be regarded as a kind of image technology, which emphasizes the transformation between images [3]. Although people often use image processing to refer to all kinds of image technology in general, the main target of the relatively narrow image processing technology is processing the image to improve the visual effect, and to lay a good foundation for upper image analysis and image understanding. The quality of digital images greatly affects the subsequent image interpretation, analysis, identification, and accuracy of measurement [4].

In the process of image acquisition, it will be inevitably affected by various factors such as the sensitivity of the sensor, noise interference and the quantization problems in A/D conversion, which leads to those images cannot achieve a satisfactory visual effect. In order to achieve the purpose of human observation or machine analyzing and identifying, some improved measurement are taken on the original images, which is called image enhancement [5]. Image enhancement contains a very wide range of content, all processing means that are used to change the structure of original image to obtain better judgment and application can be attributed to the image enhancement processing. Whose goal is to improve the quality and visual effect of image, or convert the image into a more suitable form for human observation or machine analyzing and identifying, the form of identification, so as to get more useful information [6]. The traditional method of image enhancement can be basically segmented into two categories: spatial image enhancement and frequency image enhancement [7]. Spatial domain refers to the set of pixels that composing image, and spatial image enhancement will directly compute on the gray value of pixels in image, such as gray-scale transformation, histogram equalization, spatial smoothing and sharpening processing of image, pseudo-color processing[8]. Frequency image enhancement operates on the spectral component of image after the Fourier transformation, then inverse the Fourier transformation to obtain the desired results, such as low-pass filtering technique, high-pass filtering technique, bandpass and bandstop filter, homomorphic filtering [9]. In order to adapt to the local characteristics of the image, the image enhancement method based on local transform emerge as the times require, such as local histogram equalization, contrast limited adaptive histogram equalization, the noise removal method of local statistical characteristics [10]. Now there are some disciplines combinations with image processing, which well overcomes the shortcomings of traditional enhanced transformation technique to a certain extent.

In order to solve the details problem of processing for image enhancement with Retinex algorithm, this paper proposes a Retinex algorithm based on the luminance block to enhance the image details.

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2 Standard Retinex algorithm

The basic Retinex algorithm is put forward by the idea of using three retinal-cortical system running based on the HVS, in which each operation is performed in the visible spectrum at the independent high, medium, and low wavelengths, and each independent process form a separate image, represented by *R* (*R* represents reflectance component, i.e. enhanced results). When the Retinex algorithm is applied to the digital image, the luminance values of pixel of three color channels: (R_R, R_G, R_B) are superposed to obtain the final enhanced result.

Given a digital image, consider using N paths, among which γ_k is a sequential link with the starting point of j_k and the ending point of *i* (target pixels). n_k is the number of pixels on the path of γ_k, set $t_k = 1, 2, \ldots, n_k$ is every pixel on the path, so the two consecutive pixels on the path will be x_{t_k} and $x_{t_{k+1}}$. In each channel, the value of each pixel is $I(x_{t_k})$ and $I(x_{t_k}+1)$, so the ratio can be obtained as $T_{t_k} = I(x_{t_k}+1)/I(x_{t_k})$, here, we set $T_0 = 1$ and standardize the pixel value of image into the region of [0,1], the equation is as follows:

$$R(i) = \frac{1}{N}\sum_{k=1}^{N}\prod_{t_k}^{n_k-1}\delta_k(T_{t_k}), \tag{1}$$

$$\delta_k(T_{t_k}) = \begin{cases} T_{t_k}, 0 < T_{t_k} \le 1-\varepsilon \\ 1, 1-\varepsilon < T_{t_k} < 1+\varepsilon \\ t_k, 1+\varepsilon \le T_{t_k} \le \dfrac{1+\varepsilon}{\prod\limits_{m_{k=0}}^{t_k-1}\delta_k(T_{m_k})} \\ \dfrac{1}{\prod\limits_{m_{k=0}}^{t_k-1}\delta_k(T_{m_k})}, T_{t_k} > \dfrac{1+\varepsilon}{\prod\limits_{m_{k=0}}^{t_k-1}\delta_k(T_{m_k})} \end{cases}, \tag{2}$$

where $\delta_k(R_0) = 1$ and $\delta_k(R_0) = 1$, $\varepsilon > 0$ as a fixed threshold. For the perception of luminance of human eyes is nonlinear and belongs to the exponential type. So we need to convert the above processing into the logarithmic domain processing, which has two advantages: this processing is more consistent with human visual characteristics; in the logarithmic domain processing, complex multiplication and division can be transformed to the addition and subtraction operations, which reduces the complexity of the algorithm. Below we will convert the formula into the logarithmic domain, as shown:

$$R(i) = \frac{1}{N}\sum_{k=1}^{N}\exp\left(\sum_{t_k=1}^{N}\log[\delta_k(T_{t_k})]\right). \tag{3}$$

In order to achieve the attributes of Retinex, we must know how much value is below the threshold, however, it is very difficult to complete for the image. So the threshold mechanism exists some problems that are difficult to solve. Scholars have researched and proved that the absence of the threshold has little effect on the final results of the Retinex. So we ignore the threshold mechanism, the improved equation is shown:

$$R(i) = I(i)\frac{1}{N}\sum_{k=1}^{N}\frac{1}{I(x_{H_k})}, \tag{4}$$

where $I(i)$ is the value of number *i* pixel, $I(x_{H_k})$ is the brightest spot on the path, and *N* is the number of paths. It has many similarities with Von and Kries algorithms, but the biggest difference is that the most bright spot of Retinex model is not obtained by traversing the whole image, but the path where the point is located.

This situation shows that the algorithm has a strong dependence on the image and path: different images and path for different $I(x_{H_k})$ could have different $R(i)$. At the same time, the paths of $\gamma_1, \ldots, \gamma_N$ connecting with the *i* makes the local property of Retinex algorithm better, because the possibility of finding the pixel x_{H_k} in the vicinity of *i* is greater.

Finally, we should consider that the pixel value is standardized, so $0 < I(x_{H_k}) \le 1$, $k = 1, \ldots, N$, then $\sum_{k=1}^{N}\frac{1}{I(x_{H_k})} \ge N$, for each pixel *i*, we all have $R(i) \ge I(i)$, this also explains why the processing result after Retinex algorithm is always lighter than the original image.

3 Improved Retinex algorithm

3.1 SEGMENTATION OF LUMINANCE BLOCKS

According to Webb's law in psychology $\Delta B / B = K$, *B* represents the stimulation intensity, ΔB represents the smallest noticeable difference and *k* is a constant. Introduce the background intensity to represent the stimulation intensity, different regions with different slopes, it is segmented into 3 regions: saturation region, medium luminance region and low luminance region. High luminance region affected by stimulated saturation is called the saturation region. Medium luminance region changes uniformly in luminance, rich in color information, so the main identified areas of human eye concentrate on medium luminance region. While in low luminance region, human eye almost hardly perceive the changes of luminance.

According to the background intensity and the transition rate of gray value, the luminance of each pixel is segmented into different regions. The background intensity and gradient information are used to make a two dimensional decomposition for image, so that the image pixels are into different regions according to the luminance, among which, the background intensity of $B(x,y)$ is obtained by need of the weighted value of neighborhood pixel:

$$B(x,y) = m \otimes \left[m \otimes \left(\frac{m}{2} \otimes \sum_{i} P(x,y) \oplus \frac{n}{2} \sum_{i'} P(x,y) \right) \oplus Q(x,y) \right], \quad (5)$$

where, m and n are the weights, i is the set of pixel value in the pixels that are neighborhood in up, down, left and right direction to the pixels to be processed, and i' represents the set of four points in the diagonal line of the pixel to be processed. Use the edge detection algorithm to calculate the gradient $T(x,y)$ of pixel values, which can be regarded as the transition rate of information. The biggest difference value between the image pixels is defined as IM:

$$IM = \max\left(P(x,y)\right) \min\left(P(x,y)\right). \quad (6)$$

According to the luminance threshold of B_j and gradient threshold of T_j, $j = 1, 2$, segment the luminance area of the image, there are:

$$B_1 = a \cdot IM, \quad (7)$$

$$B_2 = b \cdot IM, \quad (8)$$

$$T_1 = 0.01\beta \max\left(\frac{T(x,y)}{B(x,y)}\right), \quad (9)$$

$$T_2 = \frac{T_1}{B_2}, \quad (10)$$

The pixels in medium luminance region meet $B_1 \le B(x,y) \le B_2$, and $T(x,y)/B(x,y) \ge T_1$. The pixels in saturation region meet $B(x,y) \ge B_2$ and $T(x,y)/B(x,y)^2 \ge T_2$. The remaining pixels are in low luminance region; the luminance of the image is segmented into several regions in above way, to achieve the purpose of different regions respectively enhancing the image. The corresponding parameter is set as $a = 0.01$, $b = 0.7$, the weight of $m = 0.8$, $n = 1.6$.

3.2 ENHANCEMENT OF LUMINANCE BLOCKS

In this paper, the luminance of 3 division region of the original image are defined as: low luminance region I_1, medium luminance region I_2 and the saturation region I_3. The computation process of Retinex, do not adopt linear weighted method, but use the division results of luminance regions, to make targeted Retinex enhancement with different scales of σ, which can integrate the advantages of different scales of Gauss function.

As the medium luminance regions has the best visual effect, and is more suitable for human eye observation, this paper takes the processing of medium luminance regions as an example. Firstly, perform the filtering operation with Gauss function with the scale of σ_2 to get the input components of the region, and then remove input components from the image to get the needed reflection components, so as to achieve to enhance luminance region, here replace the original image S with the luminance I, the equation is as follows:

$$F_2 = \frac{1}{\pi\sigma_2} \exp\left(-\frac{\left(x^2+y^2\right)}{2\sigma_2^2} \right), \quad (11)$$

$$R_2(x,y) = \log I_2(x,y) - \log\left[I_2(x,y) * F_2(x,y) \right], \quad (12)$$

where, $F_2(x,y)$ is the Gauss function with the scale of σ_2, $I_2(x,y)$ is the pixel in luminance region after the division, "*" represents that Gauss function σ_2 only functions in the corresponding region. This is the form of different regions which is mentioned above respectively processed.

Similar to the calculation of medium luminance regions, the remaining luminance saturation regions and low luminance regions also select each processing method, and respectively adopt different Gauss filter at different scales to calculate in order to achieve enhancement of different luminance regions of brightness, the equations are as follows:

$$F_k = \frac{1}{\pi\sigma_k} \exp\left(-\frac{\left(x^2+y^2\right)}{2\sigma_k^2} \right), \quad (13)$$

$$R_k(x,y) = \log I_k(x,y) - \log\left[I_k(x,y) * F_k(x,y) \right], \quad (14)$$

where, $F_k(x,y)$ is the Gauss function with the scale of σ_k, I_k is the different luminance region, "*" represents that the nuclear of Gauss template is only used within the corresponding luminance regions I_k, $k = 1, 2, 3$.

Through the above calculation, the targeted respectively processing for different luminance regions get their respective regional reflection components $R_1(x,y)$, $R_2(x,y)$ and $R_3(x,y)$. Since then, the calculation of the image enhancement is completed, and the calculated results need combination, combination, the result of combination is the image enhancement that we need.

3.3 FUSION OF BLOCKS INFORMATION

There are similarities between the methods of blocks information fusion method and mean filtering, which are both based on a pixel as the center, select the appropriate window around the certain range. But the difference is the templates of mean filter is weighted form, and the value of weight depends on the selection of template. While the method of block information fusion is classification of edge information of pixels, and solve according to the proportion.

Firstly, define the results in all regions after different scales processing as: $I_1^{'}$, $I_2^{'}$ and $I_3^{'}$. The pixel points $O(x,y)$ in the region is selected as the center, and an square window of $N \times N$ around the region is selected. The proportions of low luminance region, medium luminance region and the saturation region in the window are presented by p_1, p_2 and p_3, so there is the equation according to the proportion of information fusion shown as follows:

$$I^{'}(x,y) = p_1 I_1^{'}(x,y) + p_2 I_2^{'}(x,y) + p_3 I_4^{'}(x,y), \qquad (15)$$

where the value of N is generally odd such as 3 and 5, take the window of 3×3 as an example, the center point of the matrix represents the luminance point of unknown image, the luminance of its surrounding pixels is depended on the specific image without a unified numerical value. With the refinement of window selection, the amount of calculation increases. Combining the final results of $I^{'}(x,y)$ with the components H, S of original image will get the enhanced results that we need. This algorithm only processes the luminance information of image, which causes less distortion in color and saturation for the enhanced image when compared with original image, and improves the visual characteristics of the image.

4 Practical simulation

In order to improve the effectiveness of the algorithm proposed in this paper, the simulation experiment is conducted and compared with the standard Retinex algorithm. Under the experimental conditions of strong light and weak light, this paper compares the information entropy of image enhancement of these two algorithms, the experimental results as shown below.

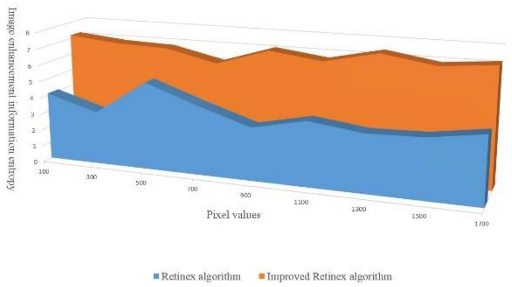

FIGURE 1 Environmental light intensity image information entropy contrast enhancement

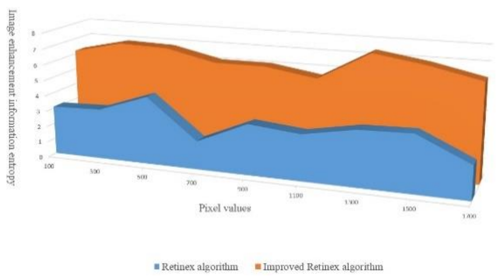

FIGURE 2 Weak light image information entropy contrast enhanced environment

From Figures 1 and 2 it can be seen that strategies of segmentation of luminance block, enhancement of luminance block, and fusion of block information adopted in this paper has improved the information entropy of the original Retinex algorithm, which means that through this improved algorithm, the details of enhancing image is more abundant.

Then, simulate the improved Retinex algorithm with example, as shown in the following graphs. Figure 3 is the original image. Figure 4 is the results of image enhancement.

FIGURE 3 Original image

FIGURE 4 After the results of image enhancement

As it can be seen from the graph, the improved Retinex algorithm proposed in this paper has good effect in the application of image enhancement.

5 Conclusions

Image enhancement refers to using a particular method to process image, to highlight useful information in the image, so as to meet specific needs or practical application. Based on the Retinex algorithm, this paper proposes the improved Retinex algorithm based on luminance blocks to optimize the details of the original Retinex algorithm. From the simulation results it can be seen that, the improved Retinex algorithm proposed in this paper has an excellent performance, and improves the information entropy of the original Retinex algorithm

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