A Novel Adaptive Retinex for Image Enhancement

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Keywords: Retinex, Image Enhancement, Histogram.

Abstract. A novel adaptive Retinex algorithm for image enhancement is proposed in this paper. This method can automatically get the histogram truncation value on the basis of the actual pixels distribution of image. In experiment, we take multi images to test and verify the novel method and other methods. The experimental results show that the proposed method is superior to other methods.

Introduction

In the process of image acquisition, there are many factors to affect the image quality, such as light condition, noise, etc. so in order to get high quality image, people usually use image enhancement technologies to improve the image quality. These technologies can be summarized as three main categories: (1) histogram-based modification methods; (2) image smoothing and sharpening methods; (3) Visual effect-based enhancement methods.

The Retinex theory is presented by Land [1-2], which is the most influential of the visual-effect-based enhancement methods, and is one of the most effective methods of image enhancement. Retinex theory can keep the balance of enhancement effect among the dynamic range compression, edge enhancement and color constancy. Now, Retinex theory is widely used to enhance night image, fog image, rain image, infrared image, remote sensing image, etc.

But, the enhancement effect of Retinex is easily affected by the scale factor; so many improved methods are proposed, such as SSR [3], MSR [4], MSRCR [5], etc.

Liu Qian, et.al [6] presented a multi-scale Retinex adaptive image enhancement algorithm based on histogram to improve the tensile effect of the image. This method has a good enhancement effect, but does not specify the influence of the truncation value on the image enhancement, only simply select a fixed value to enhance image.

Qiao Xiaoyan, et.al [7] take advantage of the differences between the original image and the filtered image by the Gauss function to correct the original image pixel value in RGB color space. the method can eliminate the color distortion, which is caused by the two pixels that have the same incident light component.

Zhenfeng Shao, et.al [8]use Butterworth filter as the center surrounding function to enhance the lightness and saturation in HIS color space, and fuse the image edge information. This method can increase the enhancement effect.

Jinsheng Xiao, et.al [9] present a fast image fusion enhancement algorithm based on HSV and RGB color space. The method can effectively eliminate the image noise, color halo phenomenon and image distortion.

In this paper, we present a novel adaptive Retinex algorithm, which can automatically get the histogram truncation value on the basis of the actual pixels distribution of image rather than to set value artificially. Experimental results show that the novel method has a better enhancement effect than other methods.
Retinex algorithm

Single Scale Retinex (SSR)

Retinex theory defines: a given original color image $S(x,y)$ can be decomposed to reflect image $R(x,y)$ and incident image (luminance image) $L(x,y)$.

$$S(x,y) = R(x,y) \cdot L(x,y)$$  \hspace{1cm} (1)

Where, $L(x,y)$ determines the image brightness dynamic range. $R(x,y)$ represents the intrinsic properties of an object, that is, the intrinsic properties of the image. $S(x,y)$ represents the reflected light image that the human eyes can receive. The basic idea of Retinex theory is to eliminate or reduce the impact of the incident image by some way, and as far as possible to retain the essence of the image.

$$r(x,y) = \log R(x,y) = \log \frac{S(x,y)}{L(x,y)} = \log S(x,y) - \log L(x,y)$$  \hspace{1cm} (2)

$$r(x,y) = \log S(x,y) - \log [F(x,y) \ast S(x,y)] = s(x,y) - l(x,y)$$  \hspace{1cm} (3)

$$L(x,y) = \log L(x,y) = \log(F(x,y) \ast S(x,y))$$  \hspace{1cm} (4)

$$s(x,y) = \log S(x,y)$$  \hspace{1cm} (5)

where, $r(x,y)$ is the output image. $\ast$ presents the convolution operation. $F(x,y)$ is the center surrounding function, define as follow

$$F(x,y) = \lambda e^{-\left(\frac{x^2+y^2}{c^2}\right)}$$  \hspace{1cm} (6)

Where, $c$ is the Gauss surrounding scale. $\lambda$ is normalization factor, which must be subjected to the following conditions

$$\int \int F(x,y)dxdy = 1$$  \hspace{1cm} (7)

The processing procedure is shown in Fig 1.

![Image enhancement procedure of Retinex.](image)

Figure 1. Image enhancement procedure of Retinex.

Multi Scale Retinex (MSR)

MSR is developed on the basis of SSR, which not only can realize the dynamic range of the image enhancement, color constancy, but also has high fidelity image. The formula is shown as following
$$r(x, y) = \sum_{k} w_k \{ \log S(x, y) - \log [F_k(x, y) * S(x, y)] \}$$

where, $K$ is the count of Gauss center surrounding function. In MSR, we usually set $K = 3$, so MSR has low, medium, and high three scales of SSR. The weight $w$ is set

$$w_1 = w_2 = w_3 = 1/3$$

Adaptive Retinex Algorithm

Adaptive image enhancement algorithm based on histogram auto-truncation[6] is to improve the image enhancement effect by setting the appropriate cut-off value. The truncation function is shown as following

$$I_{out} = \begin{cases} 0 & I_{in} \leq I_{low} \\ \frac{I_{in} - I_{low}}{I_{high} - I_{low}} \times d_{max} & I_{low} \leq I_{in} \leq I_{high} \\ d_{max} & I_{in} \geq I_{high} \end{cases}$$

Where, $I_{in}$, $I_{out}$ respectively represents the input and output values of each color channel image. $d_{max}$ is the maximum output dynamic range value of image. In color image, we set $d_{max} = 255 \cdot I_{high}$, $I_{low}$ represent the upper truncation value and the lower truncation value respectively.

$$\begin{align*}
I_{high} &= u + n\delta \\
I_{low} &= u - n\delta
\end{align*}$$

Where, $u$, $\delta$ are the mean value, standard deviation of a color channel image.

Form formula(11), we can find that $n$ is an important parameter. In reference[6], it is considered that image histogram is Gauss distribution, set $n = 3$. But in fact, the image histogram does not fully meet Gauss distribution. So, according to the actual distribution of image, we get the $n$ value by a new way. The calculation formula is as follows

$$n = \min \left\{ \frac{(ma - u)}{\delta}, \frac{(u - mi)}{\delta} \right\}$$

Where, $u$, $\delta$, $ma$, $mi$ are the mean value, standard deviation, maximum pixel value and the minimum pixel value of the color channel image respectively.

Experimental results and analysis

In the experiment, we test and verify the algorithm with multiple color images, and evaluate image enhancement effect by combining image quality subjective evaluation method with image quality objective evaluation method. The image quality objective evaluation indicators include image mean value, image standard deviation and entropy. The image mean value refers to the average value of color image brightness information, and is at the 100-150 level as well. The image standard deviation and entropy are both to reflect the details of the image enhancement, the greater the value, the more details of the image are retained. Whereas, the image color gentle degree is evaluated by human subject.
First, we compare the image enhancement effects of SSR, reference[9](SRSSR) and the novel method for image with one scale, shown in Fig.2, and Table 1, here, scale $c^2 = 10000$.

Table 1. Objective performance comparison of image enhancement methods with one scale.

<table>
<thead>
<tr>
<th>image</th>
<th>method</th>
<th>standard deviation</th>
<th>entropy</th>
<th>mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original image a</td>
<td>SSR</td>
<td>7.5093</td>
<td>5.7641</td>
<td>215.45</td>
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<tr>
<td></td>
<td>SRSSR</td>
<td>9.4726</td>
<td>7.1965</td>
<td>134.48</td>
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<td></td>
<td>novel method</td>
<td>9.4743</td>
<td>7.3497</td>
<td>135.62</td>
</tr>
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<td>Original image b</td>
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<td>8.8454</td>
<td>6.5596</td>
<td>201.82</td>
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<tr>
<td></td>
<td>SRSSR</td>
<td>9.1587</td>
<td>7.1205</td>
<td>132.71</td>
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<td>novel method</td>
<td>9.2033</td>
<td>7.3904</td>
<td>138.69</td>
</tr>
<tr>
<td>Original image c</td>
<td>SSR</td>
<td>10.135</td>
<td>5.2364</td>
<td>108.82</td>
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<tr>
<td></td>
<td>SRSSR</td>
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<td>5.1848</td>
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<td>10.318</td>
<td>5.4109</td>
<td>127.38</td>
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</table>

Second, we also compare the image enhancement effects of MSR, MSRCR, reference[9](SRMSR) and the novel method for image with one scale, shown in Fig.3, and Table 2, here, scale $c^2 = [200,1600,10000]$.

Figure 2. Comparison of image enhancement effect with one scale.

Figure 3. Comparison of image enhancement effect with multi scales.
Table 2. Objective performance comparison of image enhancement methods with multi scales.

<table>
<thead>
<tr>
<th></th>
<th>method</th>
<th>standard deviation</th>
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<th>mean value</th>
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<tbody>
<tr>
<td>image</td>
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<td></td>
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<tr>
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<td>10.215</td>
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</table>

In the experiment, we find
(1) From Fig.2 and Fig.3, the novel method can best to preserve the image color information, and has the best image color gentle degree and image sharpness.
(2) Form Table 1 and Table 2, the image standard deviation and entropy with novel method are greater than other methods, and the image mean value with novel method keeps in the range of 100-150.
By combining image quality subjective evaluation method with image quality objective evaluation method, we can draw a conclusion that the novel method has a good enhancement effect to image brightness information, color information and detail information.

Conclusions
In this paper, a novel adaptive Retinex algorithm for image enhancement is proposed. According to the actual distribution of image, the novel method can automatically get the histogram truncation value rather than to set value artificially. Combining image quality subjective evaluation method with image quality objective evaluation method, we take multi images to test and verify the novel method and other methods. The experimental results show that the proposed method is superior to other methods.

Acknowledgements
This research was supported by the National Nature Science Foundation of China under grant 61463011 and the Province Natural Science Foundation of Hainan under grant 614226.

References


