Retinex processing for automatic image enhancement using wavelet transformation

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ABSTRACT

Retinex is a method used for image processing. Image processing has a great role in Medical science. Medical images such as MRI, CT, Ultrasound, X-Ray has to be processed for proper diagnosis. Retinex technique can be used for the processing of these images. By retinex processing, it can provide better dynamic range compression, color consistency, and lightness rendition. The different methods proposed by Retinex algorithm include Light Compensation Algorithm in Color Facial Image, Retinex for bridging the gap between color images and the human observation of scenes, Color Image Contrast Enhancement by Retinex, Color Image Enhancement with Adaptive Filter. Single scale Retinex causes halation due to Gaussian filter and it does not preserve the edges. While the multiscale Retinex has a very high computational cost. So in this project, we propose retinex algorithm based on wavelet transformation which has low computational cost, i.e. it takes a lesser amount of time and higher efficiency. The input image is processed by wavelet transform. Here the Gaussian filter and retinex are applied only to the half the resolution of the image. Thus the computational cost is reduced as the number of pixels for processing is reduced and the Gaussian surround space can be small. Histogram equalization is applied to improve the visual effect. Moreover, we gain higher entropy by using clipping and gain/offset operation. At last, we compare the proposed output with that of the standard MSR output. The experimental results show that proposed method provides satisfactory image enhancement without halation.

Keywords: Single-scale retinex, Multi scale retinex, Computational cost, Gaussian filter, Histogram equalization, Halations

1. INTRODUCTION

The image enhancement is a method that processes an image so that the output image is more suitable than the original image. It improves the interpretability and perception of key features in an image. Image enhancement has been used in many fields such as transportation, aerospace, security purposes and medical fields.

The existing methods of image enhancement are low pass filtering, high pass filtering, and histogram equalization. They are useful in some applications but have some shortcomings.

There is a difference between captured image and the scene from the real world. The human visual system is better than machine when processing images. Observed images of the real scene are processed according to brightness variations. The images captured by the machines are easily affected by environmental conditions which tend to reduce its dynamic range. On the contrary, the human visual system can automatically compensate the image information by psychological mechanisms of color constancy, an approximate process of the human perception system makes the perceived color of the scene or objects remain relatively constant under varying light conditions. Thus To obtain the image comparable with scenes of the real world we use retinex algorithm.

In this paper, we propose a retinex algorithm based on wavelet transform which is fast and effective.

2. LITERATURE REVIEW

Studies on enhancing the visual effect of an image using retinex like the algorithm is a wide research area. Different methods are proposed to improve the brightness, entropy, computational cost and quality of the image. Several types
of research have attempted to overcome the problems. This section discusses the works related to the retinex processing and details the research publication briefly.

The standard multi scale retinex algorithm improved the quality of the image, but relations appeared in the high contrast area. This was improvised by using a guided filter instead of a Gaussian filter, but the computational cost was high. Another approach was to use a bilateral filter. It was inefficient as the processing time was too long, hence could not be used for real-time images. The proposed algorithm in this paper overcomes the above limitations to give a better quality image.

3. RETINEX THEORY

If Edwin Land studied light in color for many years. In 1980 he proposed the retinex theory of color to explain how we are able to see color consistently despite differences in light levels. He coined the term retinex. Retinex is a compound word formed by the combination of retina and cortex. Retina—the part of the eye, which detects color and visual cortex is the part of the brain that process information that it receives from the retina. Retinex processing a non-linear processing solution that imitates the human visual system. It provides image sharpening, color constancy processing, and dynamic range compression.

Standard retinex processing consists of two steps: estimation and normalization. The image is a product of reflectance and illumination. Reflectance is represented by estimation and normalization of illumination.

\[ I(x,y) = R(x,y) \cdot L(x,y) \]

Where \( I \) represents the original image, \( R \) represents reflectance and \( L \) represents illumination.

Jobson proposed single scale retinex (SSR). SSR is an estimation of illumination using a Gaussian filter. We can estimate image \( I \) using the Gaussian function. It represented by the equation

\[ G(x,y) = ke^{\frac{-2x^2 + 2y^2}{c^2}} \]

Where \( k \) represents normalization factor, \( c \) the scale parameter of the Gaussian function.

In SSR, artifacts appear around the edges. To overcome this problem multi scale retinex was proposed. (MSR). MSR is a combination of several SSR outputs. The MSR output is given as follows

\[ R(x,y) = \sum_{n=1}^{N} w_n \cdot R_n(x,y) \]

Where,

\[ R_n(x,y) = \log I(x,y) - \log (G(x,y) \ast I(x,y)) \]

Where \( I(x,y) \) is the original image, \( G(x,y) \) is the Gaussian surround function and \( \ast \) denotes convolution operation. But MSR has very high computational cost. It takes longer time and it has lower efficiency. The flow chart is as shown in figure1)

4. PROPOSED RETINEX BASED ON WAVELET TRANSFORMATION

The edge is the most important aspect of an image. Most of the image enhancement techniques do not preserve the edges, hence the image becomes blurred. As in here, the Gaussian filter prevents the preservation of edges. The wavelet transformation is a method of time-frequency analysis. It which selects the appropriate frequency band adaptively based on the characteristics of the signal. Then the frequency band matches the spectrum, which improves the time-frequency resolution. It helps in removal of noise in the signal. Wavelet transform converts the image into a series of wavelets that can be stored more efficiently than pixel blocks.

Steps involved in retinex processing using wavelet transform

**Step1:** Original image is decomposed into four components by applying discrete wavelet transformation i.e. LL, LH, HL and HH subbands wherein LL represents the approximated version of the original at half the resolution. LH block contains vertical edges, HL blocks show horizontal edges very clearly. HH area, where we find edges of the original image in a diagonal direction.

**Step2:** Extract LL component and apply a Gaussian filter to it. The output is given by

\[ F(x,y) = G(x,y) \ast LL(x,y) \]

**Step3:** Apply Multi scale retinex to \( F(x,y) \). In the retinex algorithm, upper and lower clipping is done so as to obtain maximum entropy. The upper and lower clipping values are obtained experimentally i.e. B. As a result, the retinex equation is modified as:

\[ R_{LL}(x,y) = \log (f(x,y) + B) \log (G(x,y) \ast I(x,y)) + B \]

**Step 4:** The proposed MSR output is obtained by histogram equalization and then taking the inverse wavelet transformation. Inverse is obtained by composition of 4 subbands O(x,y), LH(x,y), HL(x,y), HH(x,y).

![Fig. 1: Steps](image-url)
5. SIMULATION EXPERIMENTS AND OBJECTIVE ANALYSIS

A. Simulation experiments: In this paper experiments are done on multiple images which are enhanced by two algorithms. The two algorithms used for comparison are standard MSR and proposed algorithm. The three groups of images which are enhanced by these two methods are shown in the figures.

The figure 1, 2 and 3 show the image enhancement by two methods. The fig1a, 2a, 3a are taken under low light conditions. As we can see from fig 1b brightness of the enhanced image by MSR is too high, so the image may appear distorted. This is overcome in the fig1c which is the image enhanced by our proposed method as the contrast is enhanced. The fig2b shows image enhanced by MSR where halo artifacts appear at the edges. Fig 2c shows a better quality image than the MSR as the edges are preserved by removal of halations. The same results can be seen in fig 3 as well.

B. Objective analysis:

<table>
<thead>
<tr>
<th>Image</th>
<th>Parameter</th>
<th>Standard Retinex</th>
<th>Retinex-DWT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time(s)</td>
<td>5.73903</td>
<td>2.764965</td>
</tr>
<tr>
<td></td>
<td>Entropy</td>
<td>5.4081</td>
<td>5.8203</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>9.1277</td>
<td>8.5601</td>
</tr>
<tr>
<td></td>
<td>Brightness</td>
<td>128.1700</td>
<td>128.6597</td>
</tr>
<tr>
<td></td>
<td>Time(s)</td>
<td>3.2462</td>
<td>1.38963</td>
</tr>
<tr>
<td></td>
<td>Entropy</td>
<td>5.8524</td>
<td>5.8557</td>
</tr>
<tr>
<td></td>
<td>PSNR</td>
<td>10.8059</td>
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<tr>
<td></td>
<td>Brightness</td>
<td>127.3853</td>
<td>127.3784</td>
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<tr>
<td></td>
<td>Time(s)</td>
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<td>1.3520</td>
</tr>
<tr>
<td></td>
<td>Entropy</td>
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</tr>
<tr>
<td></td>
<td>PSNR</td>
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<td>9.23</td>
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<tr>
<td></td>
<td>Brightness</td>
<td>127.4606</td>
<td>127.8326</td>
</tr>
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</table>

In order to perform the objective evaluation, the paper uses the following objective evaluation index, including time(t), information entropy(IE), brightness(B), peak signal to noise ratio(PSNR). The table shows that the time of the MSR algorithm is higher indicating it has lower efficiency. Information entropy indicates the image information. A higher value indicates that the image contains more information and its quality is better. From the table, it is clear that information entropy of image enhanced by the proposed method is higher than that of standard retinex. Brightness is also increased as we can see from the table. The bigger PSNR indicates that the small difference of the image before and after image enhancement. Since the PSNR is not varied much between two algorithms the distortion is less. The table shows that the time taken by MSR algorithm is more indicating lower efficiency. But, the proposed algorithm takes less time since the algorithm is applied only to a quarter of an image.

6. CONCLUSION

In this paper, we have proposed a retina image enhancement algorithm based on discrete wavelet transformation. Here the algorithm is applied only to quarter the resolution of the original image in contrast to the standard MSR where the filter is applied to the entire image. Thus the computational cost is greatly reduced and the output image has higher entropy.

The results show that the algorithm proposed is a fast and efficient algorithm for retinex image enhancement.

7. REFERENCES


