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# Vision Image Enhancement Using Optimized Retinex Algorithm

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**ABSTRACT:** The Retinex algorithm has been used for illumination compensation, especially for night vision image enhancement. The Multi-scale Retinex with Color Restoration Algorithm (MSRCR) shows very good performance but has a high time complexity as well as introduces the so-called 'halo effect' in the enhanced images. In this paper, we extend the MSRCR algorithm to include threshold detection and Gamma correction for the enhancement of both night-time and daytime images while maintaining the quality of the output of the algorithm. The simulation results with night and day time images shows a reduction of the halo effect in the enhanced images while the overall quality of the image is maintained.

**Keywords:** gamma correction, image enhancement, night vision image, optimization, Retinex algorithm

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## I. INTRODUCTION

The Nowadays cameras are being used for a lot of applications during the night with artificial lighting providing illumination for these cameras. However, there are some applications such as driving in which cameras do need to work in different lighting conditions, even when the illumination is very low. And with the rate of accidents occurring during the night increasing, vehicles are now using auxiliary driving systems of which image processing technology is a key component [1]. Some of these driving aids, such as rear backup cameras are quite important in preventing accidents, but they cannot be of much benefit in places with poor illumination. Most modern vehicles also do not have high-end camera systems which can aid night vision enhancement like a professional camera does.Therefore, the images have to be enhanced in order to enable the driver to see obstacles and other things. There are a lot of algorithms that can be used for image enhancement, such as Histogram Equalization, Adaptive Histogram Equalization (ALE), Contrast Limited Adaptive Histogram Equalization (CLAHE) and Retinex algorithms [2][3]. However, the Retinex algorithm or variants of it is one of the most widely used algorithms currently. The Retinex algorithm was derived from the Retinex theory of human colour constancy developed by Edwin Land in 1976 [4]. This theory basically explains how the human visual system contributes towards colour perception and how it can distinguish colours under varying levels of illumination. Based on this theory, numerous algorithms have been developed in order to enhance images taken in varying illumination conditions. Retinex algorithms model any given image S as a pixel-wise multiplication of two images: the reflection image R, and illumination image L, i.e. $S = L * R$, and estimate the reflection image from the varying illumination condition L.Some work has been done so far in order to use the Retinex algorithm to process and enhance night-time images to improve visual detail [1][3][5][6][11]. Kyung et al [7] worked on using the multi-scale Retinex (MSR) algorithm for real time processing of night scene images to enhance the visibility of images from the vehicle's camera. Jobson et al [8] proposed a variant of multiscale Retinex in order to fill the gap between colour images and the human observation of scenes. Li He et al [9] also came up with an enhancement algorithm based on the Retinex theory in order to enhance images that are weakly illuminated. Hanumantharaju et al [10] developed a Multi Scale Retinex Algorithm with a modified colour restoration technique in order to enable true colour constancy to be obtained as well as make the algorithm more streamlined.Although the Retinex algorithm is one of the most widely used algorithms, it does have some drawbacks. Most notable of these effects is the so-called "halo effect", which gives images enhanced using Retinex a glow-like appearance. Other effects include the loss of visual detail and high computational complexity. Work has been done in order to reduce the effects of the basic Retinex algorithm such as the 'halo-effect' and high time complexity [4]. This paper therefore proposes a modified version of the Retinex algorithm based on the work done in [8] and [10] to improve the quality of enhanced images, reduce the halo effect on the enhanced images as well as widen the scope of the algorithm in order to improve both daytime images and night-time images. This paper is organized as follows: Section 2 gives a brief review of the Multiscale Retinex Algorithm. Section 3 describes the improved Multiscale Retinex Algorithm with Colour Restoration. Section 4 provides the results of the simulation and the conclusion is provided in Section 5.

## II. MULTSCALERETINEX ALGORITHM

From the conventional image formation model, any image can be represented as the combination of an illumination component and a reflectance component, which can be represented as shown in equation (1) below:

$$f_i(x,y) = l_i(x,y) r_i(x,y), i \in \{R,G,B\} \quad (1)$$

Where li(x,y) denotes the illumination component and ri(x,y) denotes the reflectance component of the image. The output colour image Ri(x, y) can be obtained by finding the 2D convolution of a Gaussian surround function and original image as shown in equation (2):

$$R_i(x,y) = \log I_i(x,y) - \log[F(x,y) \otimes I_i(x,y)] \quad (2)$$

Ri(x, y) is the Retinex output for the ith channel, F(x,y) is a Gaussian surround function and the convolution $F(x,y) \otimes I_i(x,y)$ is used to estimate the illumination. F(x,y) is defined as:

$$F(x,y) = K_n \times F_n(x,y)$$

$$F_n(x,y) = e^{\left( -\left(x^2+y^2\right) / c_n{}^2 \right)} \quad (3)$$

Where cn is the standard deviation of the Gaussian distribution for the 3 channels (R,G & B) and Kn is chosen such that $\iint F_n(x,y)dxdy = 1$. For the multiscale Retinex, the final image is obtained using equation (4):

$$F_{MSRi}(x,y) = \sum_{n=1}^{N} W_n R_{ni}(x,y) \quad (4)$$

A weighting factor Wn is introduced in order to combine all the scales for the enhanced image. It is assumed to be 1/3, since for the three colour components the total value is approximately 1. For colour restoration to be added to the Multiscale Retinex, equation 5 is used:

$$F_{MSRCRi}(x,y) = C_i(x,y) F_{MSRi}(x,y), i \in \{R,G,B\}$$

$$C_i(x,y) = \beta\{\log[\alpha I_i(x,y)] - \log[\sum I_i(x,y)]\} \quad (5)$$

Where $\alpha$ is the strength of non-linearity and $\beta$ is the gain constant. In order to reduce the whitening of pictures, a final equation is used in the algorithm and is as shown below:

$$F'_{MSRCRi}(x,y) = [G \times F_{MSRCRi}(x,y)] + b \quad (6)$$

Where G is the final gain and b is the offset. From Jobson et al [8], the various parameters are given in Table 1 below.

**Table 1**Constants used for the implementation for the MSRCR Algorithm

| Constant | N | $C_1$ | $C_2$ | $C_3$ | $W_n$ | α | β | G | b |
|---|---|---|---|---|---|---|---|---|---|
| Value | 3 | 15 | 80 | 250 | 1/3 | 125 | 46 | 192 | -30 |

### 2.1 Proposed MSRCR Algorithms With Gamma Correction

This paper proposes a modified MSRCR algorithm with threshold detection and Gamma correction. The sequence of the proposed algorithm is shown in Figure 1. The original image is read and separated into its R, G and B components and each channel has the Gaussian surround function estimated using equation 3. The Retinex algorithm is then implemented using equations 2 and 4. The colour restoration technique is also implemented using equations 5 and 6. With these processes completed the colour components are then combined again and the average intensity level computed.

Depending on the intensity level of the combined image, Gamma correction with a particular $\gamma$ value is applied to the image in order to minimize the halo effect. For our algorithm, after the average intensity is computed we determined two threshold levels T1 and T2 which would be the basis for the gamma value. These threshold values are constant values which were determined experimentally by finding the average intensity levels of various images after they had been processed using the MSRCR algorithm in [8]. The gamma value was then chosen in order to lighten or darken the processed image and negate or minimize the halo effect. The gamma correction was then applied using the following criteria:

$$\begin{aligned} & A < T_1, \gamma = \gamma_1 \\ & T_1 < A < T_2, \gamma = \gamma_2 \\ & A > T_2, \gamma = \gamma_3 \end{aligned} \qquad (7)$$

For the proposed algorithm we will use the constants listed in Table 1 for the MSRCR algorithm and the threshold levels and gamma values would be determined experimentally using images obtained under various illumination conditions.

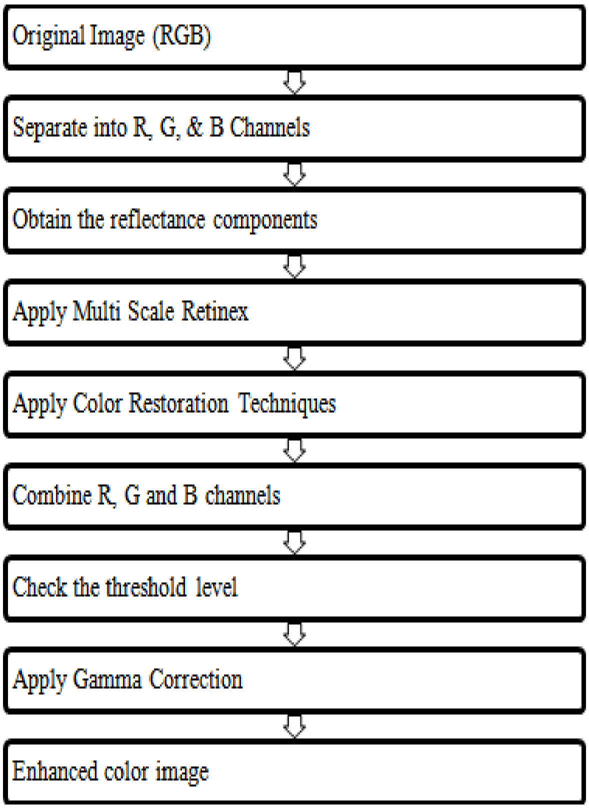


**Fig. 1**Flow Sequence of the Proposed Modified Colour Restoration Method.

## III. IMPLEMENTATION AND RESULTS

A number of experiments were conducted by sampling a number of images taken under various illumination conditions, both for the daytime and night time. The algorithm was coded and implemented using MATLAB. As examples, the results for 4 different images are shown in Figure 2. The first column of Figure 2 shows the original images. The second column shows the enhanced images obtained using the MSRCR algorithm. These images are better in showing brighter color details but appear whitened because of the halo effect. The third column shows the enhanced images obtained by the proposed MSRCR algorithm.In order to evaluate the performance of the proposed algorithm, we will consider the brightness and contrast of the obtained images and then compare it with those of the original image and with the MSRCR algorithm of [8]. The brightness of the images is obtained by calculating the image mean while the contrast is obtained by calculatingthe standard deviation of the image. The results are shown in Tables 2.The results show that the for night time images, the modified algorithm produces images which are close to the original image in terms of the average brightness level, which is the value indicated by the mean values. Images processed using the MSRCR algorithm in [8] have a high average brightness level, which is shown by the white shading and halo effect. The contrast values on the other hand, shown by the standard deviation, show that there is some color saturation in the images processed by the modified algorithm which is closer to the one produced by the color restoration technique of the MSRCR algorithm of [8]. This could be improved slightly by changing the gain values in equations (5) and (6).

(a) day street

(b) night street

(c) day cat

(d) night palace

**Fig. 2**Experiment results: original images (Left column), enhanced images by MSRCR [8] (center) enhanced image proposed MSRCR algorithm (right)

**Table 2**Criteria of Assessment (mean and standard deviation)

| | Day street | Night street | Day cat | Night palace |
|---|---|---|---|---|
| Source Image | 0.3633 (0.4810) | 0.0407(0.1976) | 0.3989 (0.4897) | 0.1747(0.3797) |
| MSRCR[8] | 0.7214 (0.1912) | 0.5459 (0.2315) | 0.7398 (0.1837) | 0.5626 (0.2413) |
| Proposed Algorithm | 0.2611 (0.2290) | 0.3254 (0.2274) | 0.2854 (0.2263) | 0.3476 (0.2136) |

## IV. CONCLUSION

In this paper we present an optimized algorithm for enhancing night-time images. In our algorithm we propose a threshold level determinant in order to reduce the halo effect, one of the issues encountered when applying the MSRCR algorithm. With this determinant, we can determine the amount of correction that can be done in order to make the enhanced images look more natural and closer to the original images. The algorithm is also optimized so as to be effective for daytime images as well. In summary, the proposed algorithm is effective at completing the task of optimizing both daytime and night-time images.

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