

# Improving the Global Impression of Brightness of the Multi Scale Retinex Algorithm for Wide Dynamic Range Pictures

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## Abstract

This paper addresses the problem of wide dynamic range scenes and presents a new method of compressing the dynamic range of wide dynamic range scenes. This method is based on the Multiscale Retinex Algorithm. The paper presents the performance of the Multiscale Retinex Algorithm on wide dynamic range pictures. Two modifications that enhance the results obtained with the original Multi Scale Retinex algorithm for wide dynamic range pictures are proposed. The first modification is obtained by the recombination of the resulting image with the original picture in a certain weight. The second modification is achieved by adjusting the histogram of the resulting picture. The modifications improve the results of the original Multi Scale Retinex Algorithm in a way that retains the global contrast of brightness and the natural impression of the resulting image. The paper explores the performance of this modified algorithm on different wide dynamic range scenes and points out its advantages over other dynamic range compression algorithms.

**Key words:** Multi Scale Retinex, Dynamic range compression, Wide dynamic range, High dynamic range, Image processing

## 1. Introduction

Display devices are limited to a dynamic range of roughly one or two orders of magnitude (8 bit which are 256 gray levels) while real scenes can reach a dynamic range of five orders of magnitude. Examples of such scenes can be scenes with both sunlit and shadowed areas, scenes compound of both indoor and outdoor details and night scenes with lighted signs.

A human observer can easily see individual objects both in the sunlit and shadowed areas, since the eye locally adapts while scanning the different regions of the scene. When attempting to display the image on a display, either the low intensity areas are underexposed and look black or the high intensity areas are overexposed and cannot be seen.

Thus, display devices limit the maximum dynamic range. An algorithm that transforms a high dynamic range scene into a reduced dynamic range image fitting the display range is needed. The reduced dynamic range image created by using such an algorithm should match the general appearance of the original scene. There are two main types of motivations that call for such algorithms:

1. There are several programs and algorithms that create synthetic images. These images accurately represent scenes comprising very wide intensity ranges that exceed the range that can be displayed on conventional devices. An example of such an algorithm is the algorithm of Debevec and Malik<sup>1</sup> that combines pictures of the same scene taken with a regular camera with different exposures into a high dynamic range picture.
2. Advances in digital imaging technology have produced imaging systems that can acquire a very wide intensity range. The intensity range exceeds the range that can be displayed on conventional devices. An example of such an imaging system is the wide dynamic range sensor presented by Yadid-Pecht and Belenkey<sup>2</sup>.

As presented by DiCarlo and Wandell<sup>3</sup> there are two main methods of dynamic range compression: tone reproduction curves (TRC) and tone reproduction operators (TRO).

These two methods, TRC and TRO, are the basis for different dynamic range compression algorithms in the literature. TRCs were described by Tumblin and Rushmeier<sup>4</sup>, Ward<sup>5</sup> and Larson and co workers<sup>6</sup>. Different algorithms based on TROs were presented by Tumblin and Turk<sup>7</sup>, Pattanaik and co-workers<sup>8</sup>, Tumblin, Hodgins and Guenter<sup>9</sup>, Adelman<sup>10</sup>, Rahman, Jobson, and Woodell<sup>11,12,13</sup>, Tanaka and Ohnishi<sup>14</sup>, Fattal and co-workers<sup>15</sup>.

In this paper, we will propose a new method of dynamic range compression of wide dynamic range pictures. In section 2, we will present a review of the original Multi Scale Retinex algorithm<sup>11,12,13</sup>. Then, we will propose two modifications that enhance the results obtained with the original Multi Scale Retinex algorithm for wide dynamic range pictures. In section 3 we will present the performance of the new algorithm on different wide dynamic range pictures and a comparison with other dynamic range compression algorithms. Section 4 concludes the paper.

## 2. An Improved Global Impression of Brightness Multi Scale Retinex Algorithm

### 2.1 The original Multi Scale Retinex Algorithm<sup>11,12,13</sup>

The multiscale algorithm is a tone reproduction operator. The algorithm estimates scene reflectances from the ratios of scene intensities to their local intensity averages. First, the scene is decomposed into a set of images that represent the mean of the image at different spatial resolutions by applying gaussian filters of different sizes. Next, a set of images that measure the scene reflectances is produced by dividing the original picture pointwise by the decomposed pictures. Then, a log function is applied to each of the images to reduce the image dynamic range. Finally, the displayed image is reconstructed by adding the compressed images together.

The equation that describes the Single Scale Retinex is:

$$\text{Single Scale Retinex (SSR)} : (1) \quad R(x,y) = \log I(x,y) - \log[F(x,y)*I(x,y)]$$

where  $I(x,y)$  is the image intensity, “\*” is the convolution operator and  $F(x,y)$  is the surrounding function:

$$(2) \quad F(x,y) = k \cdot e^{-(x^2+y^2)/c^2}$$

where  $c$  is the Gaussian shaped surrounding space constant and  $k$  is selected such that:

$$\iint F(x,y) dx dy = 1$$

The equation that describes the Multi Scale Retinex is:

$$\text{Multi Scale Retinex (MSR)} : (3) \quad R_M(x,y) = \sum_{n=1}^N w_n R_n(x,y)$$

where  $R_n(x,y)$  are different scale SSR (obtained with different gaussian functions) and  $w_n$  is the weight of each SSR. Usually, these weights are taken to be equal.

### 2.2 Applying the Multi Scale Retinex algorithm to high dynamic range pictures

According to Rahman, Jobson and Woodell<sup>11</sup> the Multi Scale Retinex algorithm has not been tested on high dynamic range pictures. In this section we report tests done on high dynamic range pictures while attempting to find the optimum number of scales and size of the gaussian kernels.

The first attempt was made with one small scale. The result is illustrated in Fig 1.

**Fig. 1 should be introduced here**

As can be noticed, the dynamic range compression of the image is very strong, the details can be noticed, but impression of brightness and illuminance are lost and the images look very “albino”.

Trying to use one large kernel, leads to a more natural image, but with stronger “halo” artifacts at the edges between high and low illuminated regions. See Fig 2.

**Fig. 2 should be introduced here**

The conclusion is that a combination of different sized kernels is needed in order to combine the strenghts of each scale and mitigate the weaknesses of each one of them. After experimenting different number and sizes of scales on different pictures we have found that the best result is achieved with four kernels, including two small sized kernels, one middle sized range kernel and one large sized kernel. The small kernels role is to supress the halos. The middle and large sized range kernels role is to give a natural impression to the image. Fig 3 illustrates some result samples.

**Fig. 3 should be introduced here**

**Midterm Conclusions**

When applying the original Multi Scale Retinex Algorithm to high dynamic range pictures - four scales, two small, one middle and one large were found to give the best results. The details in all the areas are clear. Although the “halo” artifacts are suppressed, there are still slight “halo” artifacts at the edges. Another problem is that the image looks too bright and the global contrast of brightness, i.e what region is darker or brighter in the scene, is lost . Pixels, that are in shaded regions in the original image, are brighter than pixels in the illuminated regions. Therefore, a method of restoring this information is required.

**2.3 Recombination with the original picture**

In this section a method of restoring the information of what regions are darker or brighter in the scene is proposed.

Since human eyes cannot detect absolute light power, accurate intensity levels are not required. In this section, we propose to recombine the multiscale image result with the original image in order to restore the information concerning the intensity differences between the different regions of the picture. This can retain the global contrast of brightness to the image. By taking the ratios of the scene intensities to their local intensity averages the algorithm estimates the scene reflectances. It is required to restore some of the information concerning the intensity differences between the different regions in the picture. This information is contained in the original picture for the different scales.

The following equation describes the recombination with the original picture:

$$(5) \quad R_M(x, y) = \sum_{n=1}^N w_n R_n(x, y) + w_{orig\_pic} \cdot \log( orig\_pic )$$

where  $R_n(x,y)$  are different scale SSR,  $w_n$  is the weight of each SSR,  $orig\_pic$  is the original picture and  $w_{orig\_pic}$  is the weight of the log of the original picture. Here equal weights are used for the different scales.

After experimenting with a number of pictures we have found that the large scale sized kernel can now be eliminated. By using three scales including two small sizes scales and one middle sized scale the “halo” artifacts are weaker and the natural impression of the image is not lost. Fig. 4 illustrates the image after recombination with the original picture, with three scales. As can be noticed the images look more natural and the global contrast of brightness is better than in the original Multi Scale Retinex case, which is illustrated in fig. 3. The recombination with the original picture masks the large scales influence and therefore only three scales can be sufficient.

**Fig. 4 should be introduced here**

## 2.4 Further improvement of the global contrast of brightness via Histogram adjustment

Fig. 5 illustrates histograms shapes of images that were created by the method described in section 2.3. Most of the tested pictures had a histogram similar to the histogram of the Memorial church picture. This histogram has a Gaussian like distribution of the levels. Another kind of histogram is presented in Fig. 5b. The histogram has a bimodal distribution of the gray level values. However, it can be noticed that the levels at the edges of both types of histograms are less populated than the levels in the center of the histograms. For enhancing the global contrast of brightness the following method is proposed. Lower and upper limits should be chosen in such a way that most of the pixels lie within that range. The pixels that have values above and below these limits would be clipped. The

histogram would be stretched so that 256 levels are displayed between the lower and upper limits. Fig 6 illustrates the two pictures after implementation of this method with limits of 15 and 200. The Memorial picture has important details in the shaded regions and they are slightly obscured. These levels gave the same results also for the other tested images. The method works well for both kind of histograms.

**Fig. 5 should be introduced here**

**Fig. 6 should be introduced here**

### **3. Comparison with other dynamic range compression methods**

In this section a comparison is made between our modified Multiscale Retina method, a TRC method (logarithm compression) and the method proposed by Larson and co-workers<sup>6</sup>.

**Fig. 7 should be introduced here**

In the log compressed image it can be noticed that the details in the shaded regions are obscured, the contrasts are weak, especially in the bright regions, and the picture is unclear. In the picture compressed by the algorithm of Larson and co-workers the details both in the shaded and bright regions can not be noticed. By contrast, with the modified Multiscale Retinex currently proposed the details in all the regions are shown, and a good global impression of brightness, is achieved.

### **4. Conclusions and future work**

We have presented a new method of compressing the dynamic range of high dynamic range pictures. This method enables display of high dynamic range pictures on conventional displays. It is based on the Multi Scale Retinex algorithm. Modifications to the original algorithm are done in a way that retains the global contrast of brightness and the natural impression of the resulting image. This is achieved by a recombination of the resulting picture with the original picture. Then, further improvement of the global contrast of brightness is done by adjusting the histogram limits and displaying the picture between the new limits.

The "halo" artifacts were suppressed as a result of using multiple small scales. However, the "halo" artifacts were not totally diminished. Future work would research possible further diminution of these artifacts. Another important subject for future research is hardware implementation of this algorithm so that we will be able to have a compact system for wide dynamic range scenes capture and display.

## References

1. P.E. Debevec and J. Malik, "Recovering high dynamic range radiance maps from photographs, in: *24<sup>th</sup> Annual Conference on Computer Graphics & Interactive Techniques*, Los Angeles, pp. 369-378, 1997.
2. O. Yadid-Pecht and A. Belenky, "Autoscaling CMOS APS", in: *Proc. IEEE Intl. Solid State Circuits Conf (ISSCC)*, San Francisco, California, Feb 4-7, 2001.
3. J. M. DiCarlo and B. A. Wandell, "Rendering high dynamic range images", in: *Proceedings of SPIE: Image sensors*, **vol.3965**, pp. 392-401, 2001.
4. J. Tumblin and H. Rushmeier, "Tone reproduction for realistic images", *IEEE Computer Graphics and Applications*, **vol. 13**, 6(Nov.), pp. 42-48, 1993.
5. G. Ward, "A contrast based scalefactor for luminance display", in: *Graphics Gems IV*, P.S. Heckbert, Ed. Academic Press Professional, pp. 415-421, 1994.
6. G.W. Larson, H. Rushmeier and C. Piatko, "A visibility matching tone reproduction operator for high dynamic range scenes", *IEEE Transactions on Visualization and Computer Graphics*, **vol. 3**, pp. 291-306, 1997.
7. J. Tumblin and G. Turk, "LCIS: A boundary hierarchy for detail-preserving contrast reduction", in: *Proc. ACM SIGGRAPH 99*, A. Rockwood, Ed., pp. 83-90, 1999.
8. S. N. Pattanaik, J. A. Ferwerda, M. D. Fairchild and D. P. Greenberg, "A multiscale model of adaptation and spatial vision for realistic image display", in: *Proc. ACM SIGGRAPH 98*, M. Cohen, Ed., pp. 287-298, 1998.
9. J. Tumblin, J. Hodgins and B. Guenter, "Two methods for display of high contrast images", *ACM Transactions on Graphics*, **18**, 1(Jan.), pp. 56-94, 1999.
10. H. G. Adelman, "Butterworth equations for homomorphic filtering of images", *Computers in Biology and Medicine*, **vol. 28**, pp. 169-181, 1998.
11. Z. Rahman, D. J. Jobson and G.A. Woodell, "A multiscale retinex for color rendition and dynamic range compression", in: *SPIE International Symposium on Optical Science, Engineering and Instrumentation*, **vol. 2847**, pp. 183-191, 1996.

12. Z. Rahman, D. J. Jobson and G.A. Woodell, "A multiscale retinex for bridging the gap between color images and the human observation of scenes", *IEEE Transactions on Image Processing*, vol. 6, no.7, pp. 965-976, 1997.
13. Z. Rahman, D. J. Jobson and G.A. Woodell, "Properties and performance of a center/surround retinex", *IEEE Transactions on Image Processing*, vol.6, no.3, pp. 451-462, 1997.
14. T. Tanaka and N. Ohnishi, "Painting like image emphasis based on human vision systems", in: *EUROGRAPHICS 97*, volume 16(3), D. Fellner and L. Szirmay-Kalos , Ed., pp. C253-C260, 1997.
15. R. Fattal, D. Lischinski, M. Werman, "Gradient domain high dynamic range compression", *ACM Transactions on Graphics*, July, 2002.



(a)



(b)

Fig. 1 : Two examples for the retinex method with a small scale: (a) The Memorial Church picture (b) The Trees picture



(a)



(b)

Fig. 2 : Two examples for the retinex method with a large scale: (a) The Memorial Church picture (b) The Trees picture



(a)



(b)

Fig. 3 : Two examples for the multi scale retinex method with 4 scales (a) The Memorial Church picture (b) The Trees picture

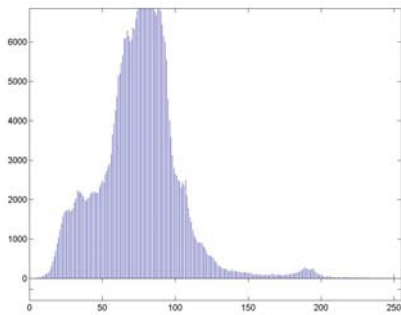


(a)

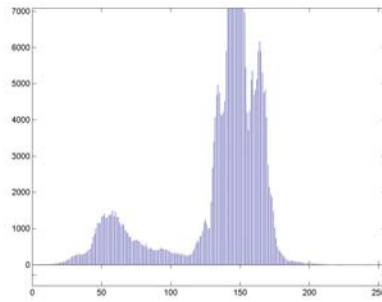


(b)

Fig 4: Two examples for the multi scale retinex method + recombination with the original picture (a) The Memorial Church picture with 3 scales (b) The Trees picture with 3 scales



(a)



(b)

Fig 5: The histograms of two images that were created by the multi scale retinex method + recombination with the double weighted original picture (a) the Memorial church picture (b) the Sunset picture



(a)

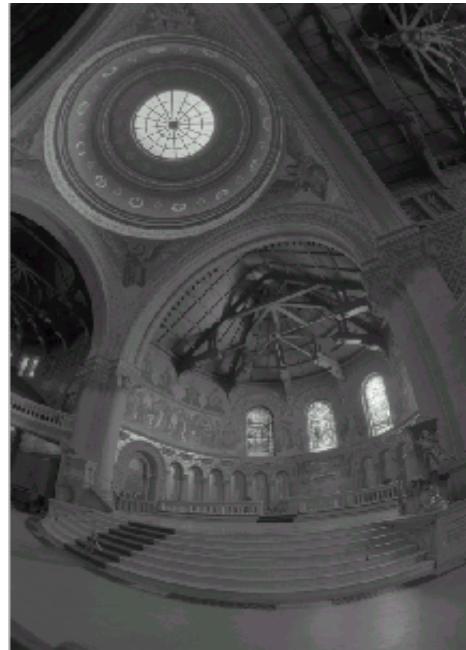


(b)

Fig 6: Two examples for the multi scale retinex method with 3 scales + recombination with the double weighted original picture + histogram adjustment (a) The Memorial Church picture (b) The Trees picture



(a1)



(a2)



(a3)



(b1)



(b2)



(b3)



(c1)



(c2)



(c3)

Fig 7: Three examples of pictures created by the following methods : (1) our method (2) logarithm compression (3) the method of Larson and co-workers

(a) The Memorial Church picture (b) The Trees picture (c) The Interior of a Church picture