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A Proposed Algorithm for Retinex Computation in Image Enhancement Applications

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Abstract

The Retinex is an image enhancement algorithm that improves the brightness, contrast and sharpness of an image. The core of Retinex computation is clearly specified in recent Matlab implementations. The recent Retinex algorithms use several free parameters to control the enhancement degree. In this paper we introduce a proposed algorithm for image enhancement using Retinex algorithm. The proposed algorithm based on the previous algorithms for Retinex computation, the major difference here is that the main control parameter for enhancement degree (enhancement factor) is computed automatically during processing according to a proposed relation introduced in this paper.

The proposed relation depends on the illumination degree of the areas (blocks) of the scene under processing this is useful for very bad illumination scenes or images. This research also shows that the proposed algorithm is useful for the images with medium illumination.

الخلاصـــــــة

الـ (Retinex) هي طريقة لتحسين الاضاءة والتباين للصور . طريقة الحساب الاساسية لهذه الطريقة تم تمثيلها بوضوح في الابحاث التي نشرت مؤخرا باستخدام (MatLab). طرائق الحساب تلك تستخدم عدة متغيرات غير محددة للتحكم بدرجة تحسين الصور. في هذا البحث نقدم طريقة مقترحة لتحسين الصور باستخدام خوارزمية (Retinex) وهذة الطريقة تعتمد على الطرائق التي صدرت موخرا لكن الفرق الرئيسي في هذه الطريقة هو ان العامل الرئيسي للتحسين (عامل التحسين) يحسب بشكل تلقائيا اثناء عملية المعالجة بالاستناد على علاقة مقترحة مبينة في هذا البحث.

العلاقة المقترحة تعتمد على درجة اضاءة المناطق (blocks) للمشهد الذي تتم معالجته وهذا يكون جيدا للمشاهد او الصور غير المضاءة جيدا. اما بالنسبة للصور التي تكون فيها درجة الاضاءة متوسطة فكذلك اظهر البحث ان هذه الطريقة مناسبة.

1. Introduction

The Retinex is an image enhancement algorithm that improves the brightness, contrast and sharpens of an image [1]. It performs a non linear spatial spectral transform that provides simultaneous dynamic range compression and color constancy. It has been used for a wide variety of applications ranging from aviation safety to general purpose photography. The original algorithm is based on a model of human vision's lightness and color developed by Edward Land [2]. Jobson et al. extended the last version of Land's model [3,4] and have since added several improvements to the original version of the Retinex including the use of multiple scales, color restoration [3] and post processing using white balance [5]. Computation of the Retinex algorithm involves performing a large number of complex operations and data transforms. The Retinex model for the computation of lightness was introduced by Land and McCann [6]. Since that time Land and his colleagues have described several variants on the original method [7,8,9,10,11]. The variants of Retinex mainly aim to improve computation and efficiency of the model while processing its basic underlying principles. The first model designed to calculate lightness was described in Land's Ives Medal address to the Optical Society of America in 1968 and later published in [6]. This lecture included a working demonstration of a primitive electronic Retinex camera. This was followed by publications and patents with additional details and improvements [7,12,13]. McCann Mckee and Tylor [10] described a study of human color constancy that included color matching experiment, the details of the lightness model and successful results of modeling the experimental data. Dynamic range compression of real images was described in a patent by Frankle and McCann [7]. This implementation used specialized hardware (International Imaging System I2S image processor with scrollable 8-bit image planes) for efficient image calculation. It described the multi-resolution approach to Retinex calculation used for computer application [11,14].

In [15] a Matlab implementation of two of the spatial techniques of making pixels comparisons. For McCann and Frankle McCann Retinex. These two algorithms required a number of iterations to perform. In [16] at each spatial scale, the viewing angle, image resolution , and the lookup table function to be applied upon computation of the main Retinex computation. These parameters where especially left unspecified. In [16,17] determined values of these parameters based on a best fit to the experimental data provide by McCann et. al.

In this paper we introduce a proposed algorithm for Retinex computation and we compare our results with the work of [15,16,17].

2. Retinex

The Retinex is a number of the class of center surround functions where each input value of the function is determined by the corresponding input value (center) and its neighborhood (surround) [1]. The input to the Retinex algorithm is an array of photoreceptor responses for each location in the image, this input represent as a three separate arrays of data one for each receptor class. Each of these spatial arrays contains the receptor class for each location in the image (pixel).

The algorithm estimates the spatial array of the lightness values for a single receptor class by computing a series of paths. Each path is computed as follows:

- Select a starting pixel (x1).
- Randomly select a neighboring pixel (x2).
- Calculate the difference of the logarithms of the sensor responses at the two positions.
- The value obtained by the pervious step is added to accumulator register for position of (pixel x2) such that:

$$A(x2)=A(x2)+\log(x2)-\log(x1) \quad \text{...... (1)}$$

where:

A(x2) accumulator registers for pixel (x2).

- Counter Register N(x2) for position x2 is incremented to indicate that the path has crossed this position. At the start of computation all registers and counters are set to zero.

The path calculation proceeds iteratively with the random selection of a neighbor of pixel x2. In general, the accumulation of position (xi) on this path is updated by:

$$A(xi)=A(xi)+\log(x1) \quad \text{...... (2)}$$

And the corresponding counter register N(xi) is incremented. Note that the first element of the path plays a special role in the accumulation for that path calculation.

The Retinex is a number of the class of center surround functions where each input value of the function is determined by the corresponding input value (center) and its neighborhood (surround) [1]. For the Retinex the center is defined as each pixel value and the surround is a Gaussian function. The mathematical form of a Retinex is given by:

$$R(x,y)=\text{Log}[I(x,y)]-\text{Log}[I(x,y)*F(x,y)] \quad \text{...... (3)}$$

where:

I: is the input image.

R: is the Retinex output image and F is the Gaussian filter (surround or kernel) defined by:

$$F(x,y)=K\exp[-(x2+y2)/\sigma^2] \quad \text{...... (4)}$$

where:

σ: is the standard deviation of the filter and controls the amount of spatial detail that is retained, and K is a normalization factor that keeps the area under the Gaussian curve.

3. The Proposed Algorithm

The previous work in [15,16,17]. For implementation single scale Retinex, depend on the model of McCann and Frankle, our goal is to implement a single scale Retinex and adjusting a controller function to get better performance. The previous method [15] implement two versions of Retinex, the first is a computer based version described by McCann [11]. The second is an older specialized-Hardware version [7]. The two versions both replace bath following with more computationally effect spatial comparison. From our experiments done on these algorithms its found that for images with high darkened regions the resultant image isn't lighted uniformly. Our modification is foxed by modifying the control mask to get more efficient algorithm for lightened images. This modification is done by altering the control mask in the manner that its varied according to the lightness of each block. The previous algorithms increase the brightness of the images uniformly, which is mean that brightening dark regions and also increasing the brightness of the bright regions, which is a drawback point. The modification is focused toward enhance the images non-uniformly, i.e. by brightening the dark regions and do not alter the brightness of the normal regions. The proposed algorithm process the image block by block with a block size of (3X3) pixels, mean of each block is computed, which is used to alter the scaling factor according to the following empirically equation:

$$\mathbf{S_F=2\text{-}mean} \quad \ldots\ldots\ldots\ldots \quad \mathbf{(5)}$$

where:

S_F: is the scaling factor

The scaling factor is approach to 1 for brighten blocks and increase to be 2 for black regions. The scaling factor is used to scale the Gaussian mask by using the following relation:

$$\mathbf{M(x,y)=F(x,y)/S_F} \quad \ldots\ldots\ldots\ldots \quad \mathbf{(6)}$$

where:

M: is the proposed mask

From the above discussion, the proposed mask is increased as the brightness of each block increased and vise versa. The proposed mask convolved with each block of the original image then the resultant image is formed by composing all the resultant blocks. The block diagram of the proposed algorithm is shown in **Fig.(1)**.

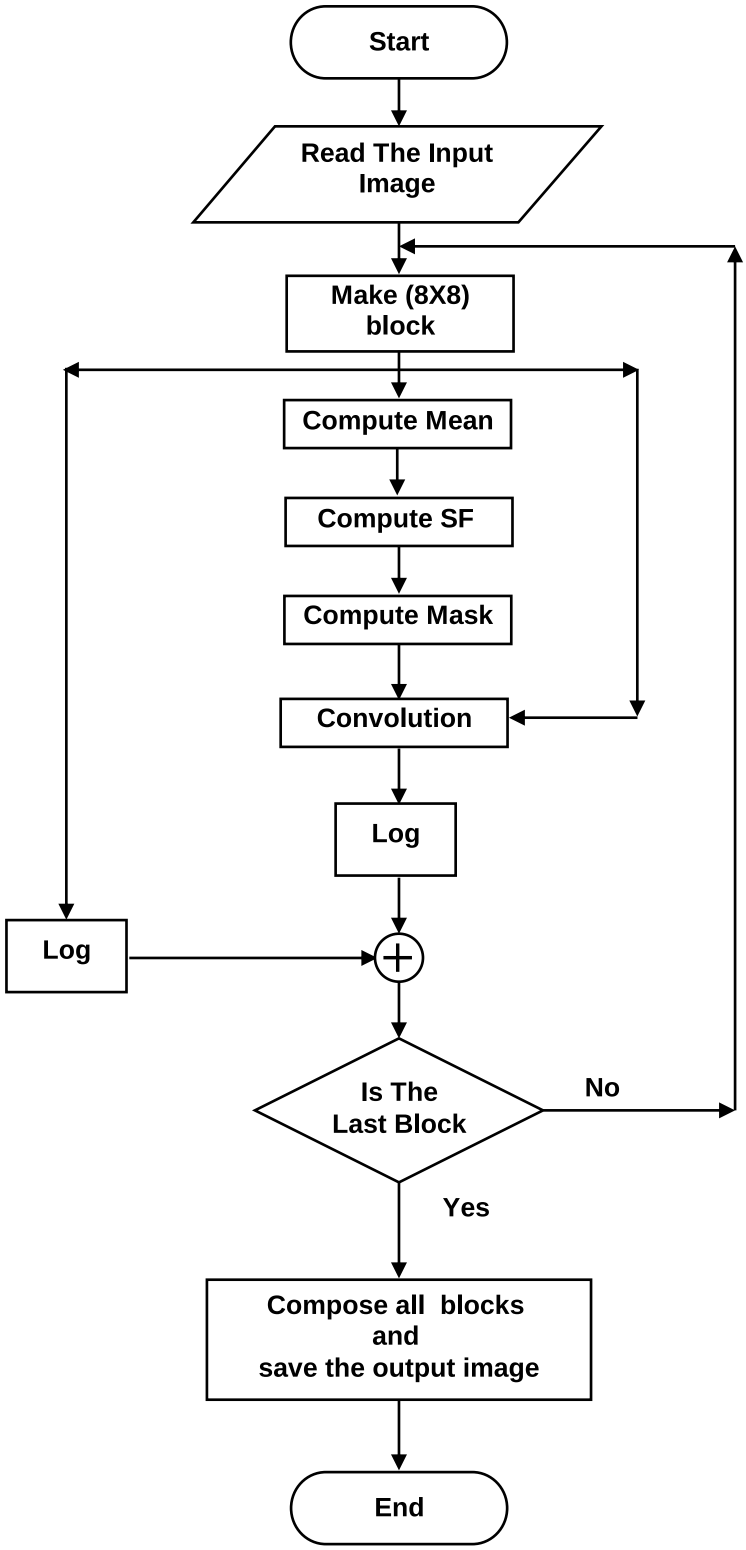

Figure (1) Block diagram of the proposed algorithm

4. Results and Discussions

The proposed image enhancement algorithm has been applied to process digital images with various illuminating conditions. The output images generally have a good quality with fine details, well-balanced contrast and luminance across the whole images. The proposed algorithm applied to a several set of images in order to show its performance, some of these images are listed in figures below. The first example is given in **Figs.(2-a,b,c and d)**, which shows a very bad lighting scene and the features of the image isn't clear , after processing this image, the resultant image enhanced and features are clear with a good degree, also the lighting of the resultant image its seems to be uniform and the processing don't affect or distort the normal regions in the image (**Fig.(2-d)**), which is an advantage of the algorithm. In order to insure that the proposed algorithm give better performance, we apply it to another image with little darkness as in **Fig.(3)**, we noticed that the resultant image has good performance and don’t blurred or saturate normal regions, which enhance the degree of features detection. The reader can easily conclude that the resultant image listed in **Figs.(2-d and 3-d)** better than the original images. The comparison between original algorithm of [15,16,17] and the proposed algorithm also shown in **Figs.(2 and 3)**. **Figures (2-b and 2-c)** showing the first image processed by the original algorithm with an enhancement factor of (2 and 3 respectively). In **Fig.(2-b)**, we noticed that little enhancement happened and the features not clear, while when increasing the enhancement factor to (3), we obtained an image with non uniformly lighting and the features are lost (**Fig.(2-c)**), which is mean that all regions of the image under processing lighted uniformly which caused brightening normal regions more than enough. In addition of that the images results from applying the proposed algorithm have a good performance than the original algorithm; the proposed algorithm not required any parameter to be adjusted by the user, which is from our point view an additional advantage of the proposed algorithm. The comparison noticed from these figures its clear that the image shown in **Figs.(2-d and 3-d)** has good enhancement degree, and it’s better than the original algorithm. Also these figures show that the proposed algorithm gives best compromise between lightening dark images and features detections. We should noted that the comparison between the proposed algorithm and the original algorithm also made for a several set of images not listed here, as we hope that images listed in the text show the performance of the proposed algorithm.

Figure (2-a) Original image

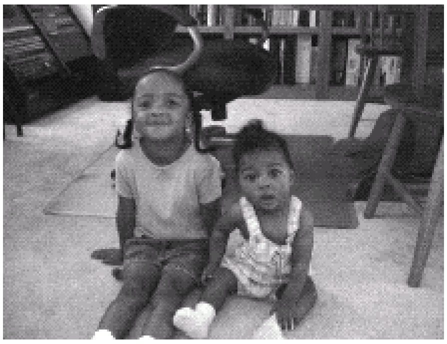

Figure (2-b) Image enhanced with enhancement factor=2 using previous algorithm

Figure (2-c) Image enhanced with enhancement factor=3 using previous algorithm

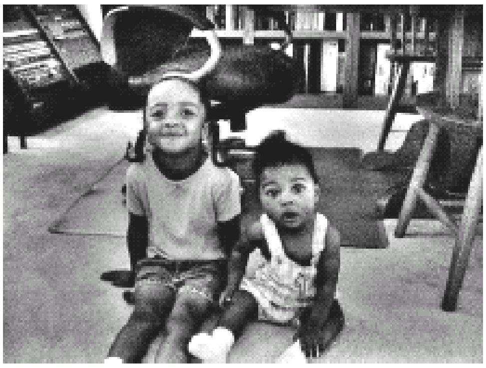

Figure (2-d) Image enhanced with proposed algorithm

Figure (3-a) Original image

Figure (3-b) Image enhanced with enhancement factor=2 using previous algorithm

Figure (3-c) Image enhanced with enhancement factor=3 using previous algorithm

Figure (3-d) Image enhanced with proposed algorithm

5. Conclusions

The efficiency of the proposed algorithm in lightening darken images is experimented by applied it to several set of images with different scene lighting. From the results obtained its found that the proposed algorithm has better performance than the original one especially for bad lighting scene, also the proposed algorithm not required an enhancement factor to be adjusted, instead of that the enhancement factor obtained automatically by proposed relation shown in the text, this enhancement factor depends on the lightness of the different area (blocks) of the images under processing that's mean that the enhancement factor varied according to the sub parts lighting on the image. This modification makes the resultant image better than the images which may results from the previous algorithms that used a constant enhancement factor.

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