A Simple Nonlinearity Upgradation Based Method of Enhancing Low Light Images

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Abstract— **As a human, we never impede ourselves to push our curiosity. As from need also from out of desire, we have always tried and trying to interpret the ambient that is bereft from light. Low light or virtually dark images are both challenging for us and our daily gadgets and cameras. An algorithm, with some notable observations and related works comparison, has been presented in this study. A captured image to be zero has been freed by adding a very negligible value with every pixel. After that, the maximum bright channel has been extracted and upscaled using gamma law and normalized intermediate bright portion of the image. Following this, the major contribution has applied and so saturation correction and value substitution with the original raw image are allowed us to reconstruct the image with better intensity, as described in the methodology. Throughout the study, simplicity, speed, and quality assurance have been focused on. According to the result of our study, the time requirement is 0.09s with the average lightness order error (LOE) value 2.13 and all the findings of the study have been presented at the later portion of this paper.**

Keywords—Gamma law, saturation correction, LOE.

I. Introduction

The Images being taken during dawn, night or in an area where the presence of light is too shallow, are hardly visually comfortable. These images are familiar to us as low light images. Enhancement for this type of images has started more than a decade ago and still going on. The recent development of the mobile camera, digital camera are being accelerated the demands of common people to be pleased with the highest quality of images details. In the field of robotic application, object detection and various information are extracted from images for controlling it efficiently and exactly. Autonomous robots, with processor capacity limitation, are also being faced acute problem in the low light environment. They cannot extract the information due to absent of perceptual quality of low light images. Using low complexity and speedy method, low light image enhancement is the only solution in this case.

In the processing of low light image enhancement, let's take a low light image and let it pass through some algorithmic steps for rendering the highest quality is possible. It is hardly an easy task in terms of fidelity, visual aesthetics, perfect luminance, balanced saturation, and computational complexity. For example, some of the world's top tier companies have introduced their smartphone with highly advance low light imaging performances. Still, they have suffered from a significant amount of color saturation problem [1]. Their images are brighter than the original scenario but the lack of original color tone is very hard to miss with bare eyes. Another scenario concerns the fickle problem where the presence of RGB noise is salient due to unconstrained enhancement. This situation can be mitigated through a little effort of details-aware smoothing, eventually, exacerbate the computational complexity of the total enhancement procedure.

In this study, Low light image enhancement has been mainly focused. A guided enhancement method has been presented which can be dealt with poorly illuminated images from various luminance settings. The major contribution of this study is computationally light. Beside this, we have proposed an efficient guided approach which allows us to preserve the color tone close to the original scenario. After balancing the brightness to a desirable label, unlike other studies, the proposed study mimic the saturation of the original scenario and dye that information on the intermediate processed image. This strategy gives us the final output image, which is both richer in color context and brightness. Before describing our proposed method, some of the major works in this area and their contribution and possible limitations will be addressed.

When it comes to deal with low light enhancement, a surfeit amount of work is available out there to provide a better possible image. Not all of those studies but mostly follows a common classification in terms of methodical relationship. One of those classes is closely associated with the basic concept of image enhancement through histogram equalization. These methods provide the necessary steps and formulations to manipulate the image in order to fashion the desired output. Following this, retinex based modeling are available and they primarily deal with reflection and illumination. And last of these classes is the area of image filtering [2]-[5]. Compared to the other two classes, this section is less homogenous and often exploits ideas like optimization, tone mapping, exposure estimation. Histogram-based approaches mostly deal with histogram modification. A method like histogram equalization, contrast-limited adaptive histogram equalization, weighted average histogram equalization- are popular among histogram based enhancement study [6]. They are very simplistic in nature and very much effective in contrast enhancement applications. They have also some weaknesses like over contrast enhancement and insensitivity toward image noise [7]. This undesirable feature results in exponential noise amplification. Basic Histogram also suffers from color distortion, often produces over saturated

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images which tend to be lighter than the original image instead of being brighter. Also, these limitations are not invincible and being overcome by layered difference representation methods where dynamic stressing is possible. Although free from the previous shortcoming, it suffers from insignificant enhancement at a very dark region [8].

Camera Response Model (CRM), High Dynamic Range (LDR), Adaptive Histogram Equalizer (AHE) and Retinex theory are very popular among researchers due to their versatile applications. Retinex theory works on the basis of reflection of the original image and its illumination. Some of the retinex based enhancement algorithms work on the basis of reflection enhancement and others on illumination enhancement. Single scale retinex and multiscale retinex are the basic division of retinex based algorithms [9][10]. The common trade of the algorithm usually associated with the brightest channel estimation and darkest channel estimation. The last set of enhancement is based on the filtering procedure. This method is generally concerned with global, local convex optimization. A noteworthy feature of this type is fast computational speed. This allows us to enhance the image properly while preserving the right color tone. But they are hardly capable of enhancing very dark images [11].

This paper is structured as follows. The very beginning section contains the introduction of this study. Following that, the proposed methodology is described in section II. In section III, our study has been compared with other major work and detailed comparative analysis being denoted. In the final section, the paper is concluded with mentioned references.

II. Methodology

First, the study is aimed to design a way of enhancing low light images with the core concept of simplicity. In order to enhance, the pixels with value zero are dealt with first. I(x,y) is considered as the input image, where x and y are denoted the individual pixel position. 〖I(x,y)〗_min, the minimum pixel greater than zero, by sorting, has been determined and then this value has been added with every pixel. This operation helps to reform the image in a desirable fashion where the pixel with zero value is absent and also helps in algebraic operation later. The current image's pixels may exceed the highest limit of pixel value due to adding 〖I(x,y)〗_min and to remove this scenario, the whole image has to be normalized. This action is necessary for removing extraneous brightness from the edge or corner or upper boundary of the image, presumably where the pixels are brighter than all other pixels for the natural image. This step is formulated as follows:

$$I_r = (I(x,y) + I(x,y)_{min}) \quad (1)$$

$$I_{norm}(x,y) = I_r(x,y)/I_r(x,y)_{max} \quad (2)$$

An image can be presented by various color lab formulation. For this particular study, HSV color space has been decided to be used. The third channel of the HSV transformed image is for showing value, upholding intensity amplitude information and the second channel is for saturation and color richness dimension [12][13]. Let's define I_(o) as the HSV transformed image by applying RGB to HSV transformation. This information is important at the later stage. At this stage, the maximum channel out of the image has been extracted. This method is trivial but very much helpful to design or restrict the pixel manipulation-based algorithms. The matrix contained maximum luminance regardless of the channels can be written by extracting the maximum intensities from those images. If R, G, B denotes the three individual channels of the image I_norm (x,y), then the maximum channel is:

$$I_{max}(x,y) = max(R_{(X,y)}, G_{(X,y)}, B_{(X,y)}) \quad (3)$$

This is a single dimensional matrix, carried maximum pixel value for a given image. Further operations have been continued on the basis upon this particular matrix. An intermediate variable N is considered which is consisting I_max(x,y). It has been observed that if a matrix, contained pixel information, featured with less nonlinear relationships among the pixels, a contrast enhancement procedure never bring satisfactory result. For this reason, the following equation is used to enhance nonlinearity.

$$N_{nonlinear} = \frac{(N - N_{min})}{(N_{max} - N_{min})} \quad (4)$$

After that, gamma correction has been applied for minimizing any undesirable intensity distortion, possibly happening by equation (4). The gamma corrected matrix is expressed as follows:

$$N_{c} = (N_{nonlinear})^{\gamma} \quad (5)$$

here, the value of γ is varied from 0 to 1; for this algorithm, γ =0.47 has been used. As mentioned earlier, the HSV color dimension would be dealt, reasonably V or value channel is the indicator of the pixel intensities. So, this new matrix N_(c) is considered as a new value channel for the original HSV transformed image. Using this, the image I_ (in) has been reconstructed with better brightness but it suffered from the proper saturation as shown in Fig. 1.

Fig. 1. Intermediate image with undersirable color saturation.

In order to overcome this problem, the following algorithm is used with swapping operation. S_(o) is considered as saturation channel of the I_o and S_(in) as saturation channel of I_(in).

For swapping their values, the steps noted are followed:

- $n = L;\ where, L = W * H$
- $S_o\,(x, y)\ and\ S_{in}\,(x, y)$ denoting any member of S_o and S_{in} and the output matrix is S_{ni}
- $S_{ni}\,(x, y) = S_o\,(x, y) + S_{in}\,(x, y)$
- $S_{in}\,(x, y) = 0$
- Repeat previous step for 1 to n.

After applying this, the desired saturation channel is constructed and concatenated with I_(in). The algorithm, introduced in this study, is the pre-eminent factor which has led the output to such a stunning one and the output are shown in Fig. 2. For this study's data and findings, MATLAB software has been used. More results and experimental outlooks are described in the following section.

Fig. 2. Final image with desirable color saturation.

III. Results and Discussion

Various factors are evaluated for the purpose of image enhancement. Like the other studies, there can be evaluated with both qualities and quantities speculation. Here, zero deviation is maintained from this philosophy. The major contribution, along with the brightness enhancement, is the color restoration. Also, this study has been managed to design in a way where the formulation of output is less noisy even without the help of light edge ware smoothing. In this section, some major factors are focused like brightness, the color tone also computational matter like timing, qualities matter and lightness order error.

At the first phase, some intensity related output with compared algorithms MSRCR [14], LIME, Dong, NPE [15], SRIE [16], and camera response model (CRM) [17] are shown in Fig. 3.. At this stage, two different images are used with a very stark difference in terms of ambient scale. The first image is purely inside the room and with a light touch of natural sunlight and no artificial light. By inspecting this and keeping it in mind, the difference can be seen in the processing of result others are significantly far away from this study approach. Most notable among others, CRM has produced a very good rise at intensity level but lost the natural color and warmth of the image. The output from the SRIE is good in preserving color compared to other methods but less efficient in raising the intensities. If more deeply are looked, its prominent that image produced by the study of Dong et al. is clearly producing the image which is unnatural and surrealistic in its own reflection. Apart from these images, others are produced the washed version of the original image. Finally, the proposed study's image is completely warm compared to others and brighter also but not the brightest. Being brightest among others is not the goal, hence our aim is to preserve the brightness and color that is perceptually right to our mind. When it comes night, all of these algorithms have given an output that either be too saturated or too white or too boosted that results in inter-pixel stark contrast or too much rich with fickle. These possible scenarios are considered, from the output it is clear that the proposed algorithm's image has been produced in a way which is freed from prior mentioned situations.

Some of the other's output cluster is shown in Fig. 4. They are eccentric in terms of their brightness. Their brightness is such adequate that does not require further manipulation. Also, they are very rich in their color tone. The proposed algorithm has successfully restored the original color of the images and applied it all over the image without destroying the dimensional harmony. To be specific, if the brightness is merged from one axis and color tone from another axis, the image cannot be expected with a stunning look. Here this merging has been completed successfully. Some important figure has not been presented due to space limitation.

Timing efficiency has been concerned in the current discussion. Our method is not the fastest among the others but faster for sure. It is observed that sometimes optimization-based methods like CRM work better in terms of speed. Also, due to simplicity gamma correction operation also operates faster but it is not to be a completed method. Proposed algorithm's timing outcome has been presented in Fig. 5.1 and Fig. 5.2. with some other algorithms timing comparisons. Histogram equalization, adaptive histogram equalization, gamma correction, CVC [18] and LDR [19] have been picked. For solely timing comparison, compared result of noted HE, CVC, LDR, AHE, and proposed algorithm, a table has been presented.

With some exceptions, it can be said that our study is produced results that desirable so far. To provide a much stronger basis for the study, lightness order error (LOE) [15] matric has been used.

Fig. 3. Here some comparisons among various algorithms. Top left is inpur. Then, followings are a) MSRCR b) LIME c) Dong d) NPE e) SRIE f) CRM and Our algorithm.

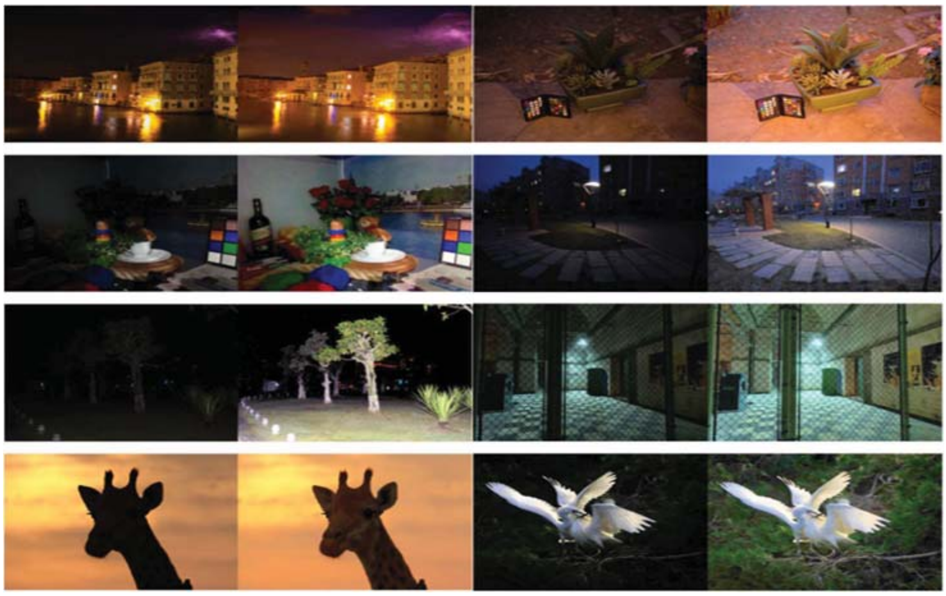

Fig. 4. Here some visual outputs of this study presented for various images.

Lightness order error empirically is calculated the subtlety alteration of boosted outcomes for a given image. This matric is defined as follows:

$$LOE = \frac{1}{M}\sum_{i=1}^{M} \Delta_r(i) \tag{6}$$

where $\Delta_r(x)$ is comparative order variance of the lightness between the original image and its boosted form, M stands for the pixel number.

It can be defined the $\Delta_r(i)$ as follows:

$$\Delta_r(i) = \sum_{i=1}^{M} U(I(i), I\,(j)) \oplus U(I'(i), I'(j)) \tag{7}$$

$I'(i), I(i)$ are the extreme values among three color channels at location i of the input images and the boosted images, respectively. The function U(a,b) yields 1 if a >= b, otherwise it gives 0 . The lesser the value of the matric, the better the output. The comparative demonstration is presented in table 1.

Analyzing both timing comparisons and Lightness Order Error (LOE) matric table for the input images, LDR is the fastest one and it takes 0.07s, 0.11s, 0.08s, 0.08s, and 0.07s and the proposed methods 0.06s, 0.07s, 0.07s, 0.08s and 0.09s for five different images from low to high brightness. LDR is almost .02s faster than proposed methods but it suffers in LOE matric test. The value of LOE matric is almost 0.69 points higher than the proposed methods. The lowest value of LOE for the input images is 2.79 where the proposed method is 2.00. This low value of LOE matric leads the proposed method over LDR. HE and AHE also take less time but badly need the improvement of LOE matric. Other methods suffer from both complexity and high LOE values.

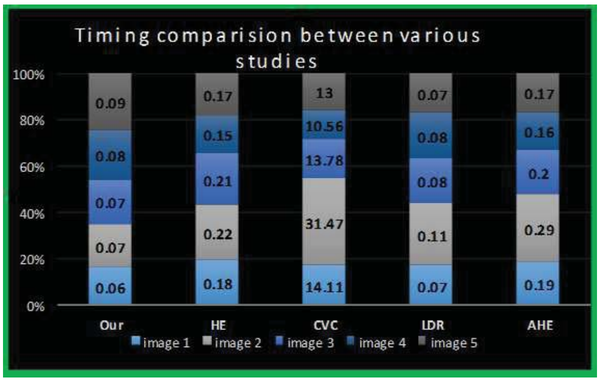

Fig. 5.1. Timing comparison with enhancement various images, various algorithms.

Fig. 5.2. Timing comparison with enhancement various images, various algorithms.

TABLE 1: COMPARATIVE ANALYSIS OF LOE MATRIC

Method	Lighthouse	Vessel	Castle	Bird	Lincoln Statue	Giraffe	Room
HE	4.28	4.62	4.70	4.25	4.84	4.26	4.35
AHE	3.16	3.30	3.25	3.80	4.69	3.95	3.43
GC	3.78	4.72	3.85	3.70	4.36	3.19	4.03
CVC	3.16	3.17	3.70	3.47	3.35	3.02	2.96
LDR	3.03	2.96	2.79	3.31	3.45	2.98	3.30
MF	3.81	3.22	3.84	3.43	3.90	3.91	3.73
LIME	3.16	3.91	3.42	3.24	3.57	3.95	3.88
Proposed	**2.03**	**2.10**	**2.10**	**2.00**	**2.25**	**2.02**	**2.13**

IV CONCLUSION

From the above analysis and demonstration, it can be inferred the odds and evens of our method properly. Various methods have been suppressed in terms of practical analysis. It can be said that our method is capable of producing an image that is better but not the ultimate. The image manipulation algorithm has been modified to overcome the previous study drawback with considerable simplicity, speed and quality assurance and applied successfully in this study. So this method is a suitable one in the field of robotic applications for its simplicity and speed. It has demonstrable its superiority with some foibles. In the future works, current's drawbacks will be overcome with the help of data science-based approach and a method will be developed to extract information from low light images

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