# Enhancement For Image Capture Under Non–Homogenous Lightness Using Retinex Techniques

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## Abstract

In the present work retinex algorithm have been applied to enhance the capture image under nonhomogenous lighting, such enhancement algorithm can effectively enhance the image contrast, compared with enhanceme nt histogram equalization algorithm. The results show that the image after enhancement has the best contrast than the image before enhancement. Study results showed that lighting intensity distribution of imaging system source represents a linear relation with voltage. The diagram was approximated to a nearest straight line function. There inverse proportion between lighting intensity of imaging system source at the right side and lighting intensity of imaging system source at the left side of line cut from the width and height of test image , in the present study statistical characteristics of captured images were calculated with different lighting intensities before and after enhancement technique.

Keywords: lightness , retinex , image quality, enhancement image.

## Introduction

The visible portion of the electro- magnetic spectrum extends from about 380 to about 780 nanometers is called light. The Illuminating Engineering Society of North America defines light as radiant energy that is capable of exciting the retina and producing a visual sensation. Light therefore, cannot be separately described in terms of radiant energy or of visual sensation but is a combination of them [1]. Radiometry is the study of optical radiation light, ultraviolet radiation, and infrared radiation. Photometry on the other hand is concerned with humans visual response to light Radiometry is concerned with the total energy content of the radiation, while photometry examines only the radiation that humans can see. Thus the most common unit in radiometry is the watt (W), which measures radiant flux (power), while the most common unit in photometry is the lumen (lm), which measures luminous flux. For light at other wavelengths, the conversion between watts and lumens is slightly different, because the human eye responds differently to different wavelengths, radiant intensity is measured in watts/steroidal (W/sr), while luminous intensity is measured in candelas (cd, or lm/sr) [2,3].The human eye is more sensitive to some wavelengths than to others. This sensitivity depends on whether the eye is adapted for brightness or darkness because the human eye contains two types of photoreceptors cones and rods. When the eye is adapted for bright light, called photopic vision (luminance levels generally greater than about 3.0 cd/m$^2$), the cones dominate. At luminance levels below approximately 0.001 cd/m$^2$, the rods dominate in what is called scotopic vision. Between these two luminance levels, mesopic vision uses both rods and cones. Fig.(1) shows the relative sensitivity to various wavelengths for cones (photopic) and rods (scotopic).

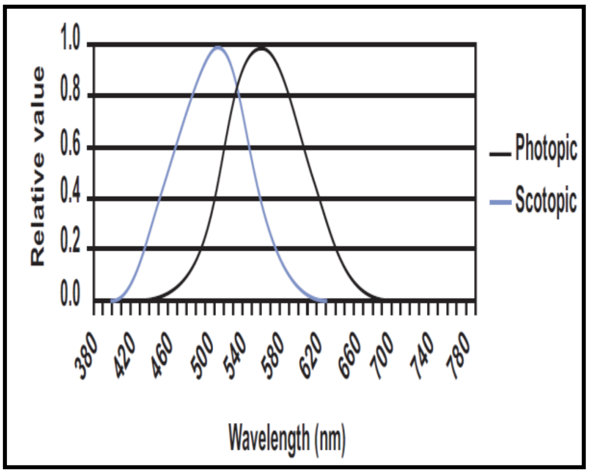



***Fig.(1) Relative Sensitivity function versus wavelength [4, 6].***

The curves represent the spectral luminous efficacy for human vision. The lumen is defined such that the peak of the photopic vision curve has a luminous efficacy of 683 lumens/watt. This value for the scotopic peak makes the efficacy the same as the photopic value at 555 nm. The scotopic vision is primarily rod vision, and the photopic vision includes the cones. The previous work in color image processing techniques enhancement, will be given below:

- The researchers Zhixi Bian and Yan Zhang in 2002 study Retinex Image Enhancement Techniques Algorithm, Application and Advantages. They will implement Single scale retinex(SSR), multiscale retinex (MSR), and color restoration method for MSR(MSRCR) with gain/offset. Where they adjust the gain/offset parameters to adjust most of the pixels values to display domain and clap small part of the values to improve the contrast. Comparisons with other image enhancement techniques will be made [7].
- Yaoyu cheng, Yu wang and Yan hu study in 2009 introduce image enhancement algorithm based on Retinex for Small-bore steel tube butt weld's X-ray imaging then determine the characteristics of X-ray images and the inadequacy of conventional enhancement methods then propose variable framework model of Retinex algorithm for the X-ray image enhancement, improve the detection efficiency and quality [12].

## Retinex Theory

Color is important information source to describe, distinguish and identify an object for human and other biological visual system. In the image, the object can be displayed in different color saturation and has nothing to do with the change of the light. The human's visual perception is more sensitive to the reflection light of the object's surface [7,12]. Retinex theory is introduced by Land to explain human's visual model, and establish illumination invariance model of which the color has nothing to do with. The basic objective of retinex model is carring out image reconstruction, making the image after reconstruction the same as the observer saw the images at the scene. Retinex balance three aspects in compress the dynamic range of gray-scale, edge enhancement and color constancy, which can be use with different types of images and self-adaptive enhance. Retinex basic principles are to be divided into an brightness image and reflection image, then enhance images to achieve the purpose by reducing the impact of image brightness on reflection image. According to Land's retinex model, an image can be defined as $S(x, y)$, is shown as Fig. (2).

$$S_{(x,y)} = R_{(x,y)} \cdot L_{(x,y)} \quad \text{......(1)}$$

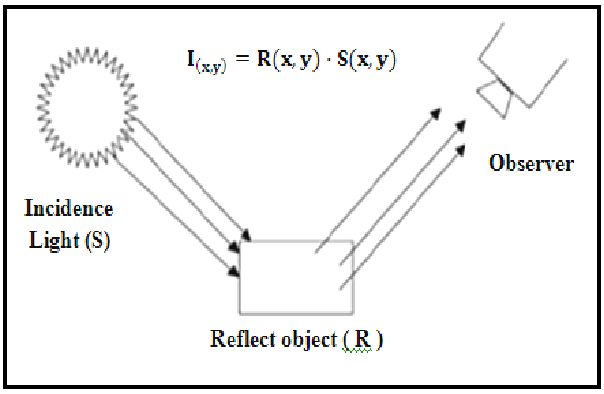



***Fig. (2) diagram of Retinex [6].***

Where, L expresses the brightness of the surrounding environment, and R is the reflectivity of objects that includes details of the characteristics of objects. The algorithm process of Retinex shown in Fig.(3).

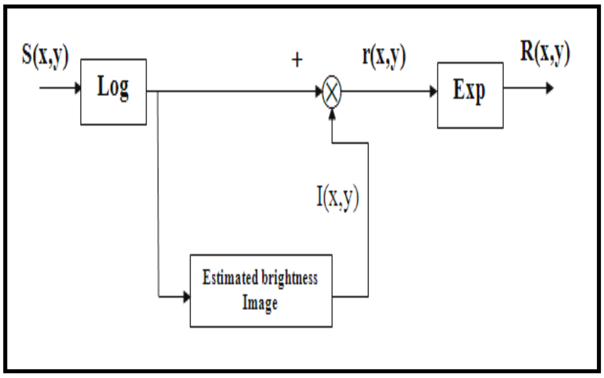



***Fig. (3) The algorithm Process of Retinex [6].***

The Retinex Image Enhancement Algorithm is an automatic image enhancement method that enhances a digital image in terms of dynamic range compression, color independence from the spectral distribution of the scene illuminant, and color/lightness rendition. The digital image enhanced by the Retinex Image Enhancement Algorithm is much closer to the scene perceived by the human visual system, under all kinds and levels of lighting variations, than the digital image enhanced by any other method .The multiscale retinex (MSR) is explained from single-scale retinex (SSR) we have [6,8] :

$$R_{i(x,y,c)} = Log[I_{i(x,y)}] - Log[F_{(x,y,c)} \otimes I_{i(x,y)}] \quad ............(4)$$

Where $R_i(x,y,c)$ the output of channel $i$ ($i \in$ R,G,B) at position x , y, and c is the Gaussian shaped surrounding space constant, $I_i(x,y)$ is the image value for channel $i$ and symbol $\otimes$ denoted to the convolution and $F(x,y,c)$ is the Gaussian surrounds function that is defined as [5,10] **:**

$$F_{(x,y,c)} = k \cdot e^{\frac{-(x^2-y^2)}{c^2}} \quad ................................(5)$$

k is the normalization constant that can be determined as follows :

$$\iint F_{(x,y,c)}\, dxdy = 1 \quad ....................................(6)$$

The MSR output is then simply a weighted sum of the outputs of several different SSR output where [8, 10]:

$$R_{MSRi}(x,y,w,c) = \sum_{n=1}^{N} w_n R_i(x,y,c_n) \quad ...............(7)$$

Where N is the number of scales, $R_i(x,y,c_n)$ the i'th component of the n'th scale, the i'th $R_{MSRi}(x,y,w,c)$ spectral component of the MSR output and the $w_n$ weight associated with the n'th scale, in which $\sum_{n=1}^{N} w_n = 1$.

The result of the above processing will have both negative and positive RGB values, and the histogram will typically have large tails. Thus a final gain-offset is discussed in more detail below. This processing can cause image colors to go towards gray, and thus an additional processing steps proposed in [8 ] :

$$R' = R_{MSR} * I_i'(x,y,c) \quad ...................................(8)$$

Where $I_i'$ is given by the following formula [5]

$$I_i'(x,y,a,b) = bLog\left[1 + a\frac{I_{i(x,y)}}{\sum_{i=1}^{3} I_{i(x,y)}}\right] \quad ....................(9)$$

Where we have taken the liberty to use log (1+x) in place of log(x) to ensure a positive result. In a value of 125 is suggested for (a); for we empirically settled on a value of (b= 100) for a specific test image. The difference between using these two values is small. In formula (9) a second constant is used which is simply a multiplier of the result, and the final step is gain-offset by 0.35 and 0.56 respectively. The present research uses: ($w_1=w_2=w_3=1/3$) and ($c_1=250$, $c_2=120$, $c_3=80$) [5].

## Gamma Characteristics Camera

The output signal level characteristics with respect to the light received by the TV camera imaging element is called the camera's gamma characteristic. The output signal level I that corresponds to the brightness (optical power) of the incident light, P, is approximated by the following relation [11]:

$$I = KP^{\gamma} \quad .....................................................(10)$$

The gamma ($\gamma$)value indicates the degree of nonlinearity, $\gamma$ =1 means that the output signal level is proportional to the incident light. When the TV camera is used for surveillance or other such purposes, $\gamma$ value of about 0.7 is suitable [9, 11].

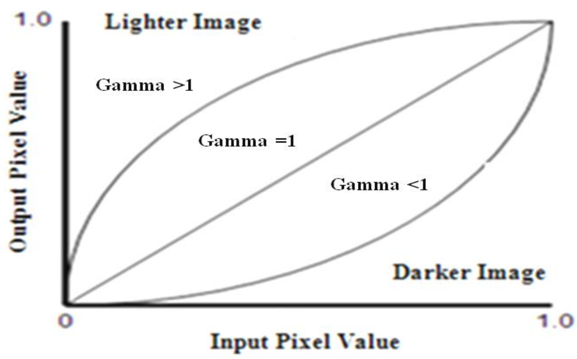



***Fig.(4) Show gamma less than one and gamma greater than one.***

In Fig.(4), the pixel values range from 0.0 representing pure black, to 1.0, which represents pure white. As the figure shows gamma values of less than 1.0 darken an image. Gamma values greater than 1.0 lighten an image and a gamma equal to 1.0 produces no effect on an image. Some cameras allow switching of the $\gamma$ value. Most cameras that allow the $\gamma$ value to be selected give you the two choices of $\gamma = 1$ or $\gamma = 0.45$.

## Linear Least Square Fitting method

The most common method for fitting a regression line is the method of least-squares. This method calculates the best-fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable, and the other is considered to be a dependent variable .A linear regression line has an equation of the form:

$Y = a + bX$,

Where $X$ is the explanatory variable and $Y$ is the dependent variable. The slope of the line is $b$, and $a$ is the intercept (the value of $y$ when $x = 0$).

**Method**

Imaging System shoed in Fig.(5) was designed. Imaging System consists of a dark box painted inside with black color. Dimensions of the box are (61x 74 x 120) cm. the distance between test image desired for imaging and the light source is 120 cm. The dark box includes light source (tungsten bulb) in one of its corners. The same corner at the bottom of light source has an opening for imaging to put the camera on it. At the opposite side test image to be set (A4 size) at different lighting conditions whereas lighting intensity is controlled using electronic circuit.

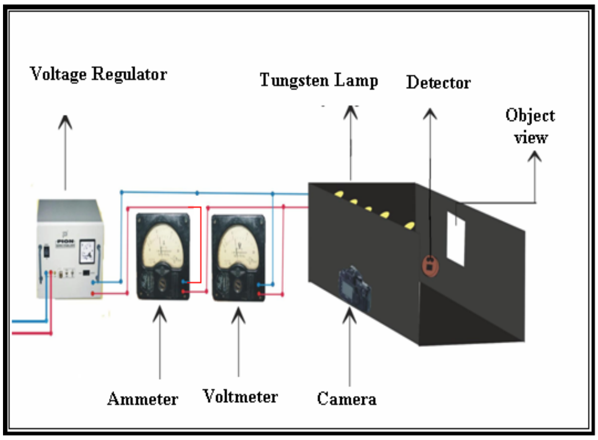



***Fig.(5) Imaging system design.***

This study adopted a test image captured with Sony Digital Camera with different lighting intensities by the voltage applied on the light source. eleven images were captured when using a light from the right side along with eleven images were captured when using a light from the left side at different lighting conditions of light source. Images resulted from both different lighting conditions are showed in Fig.(6, 7).

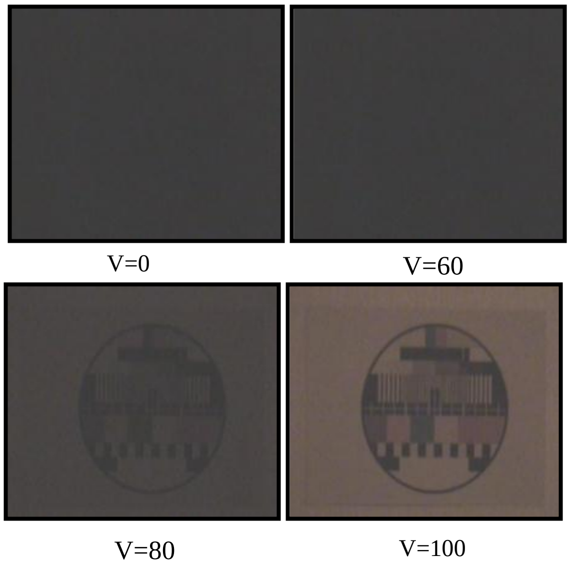
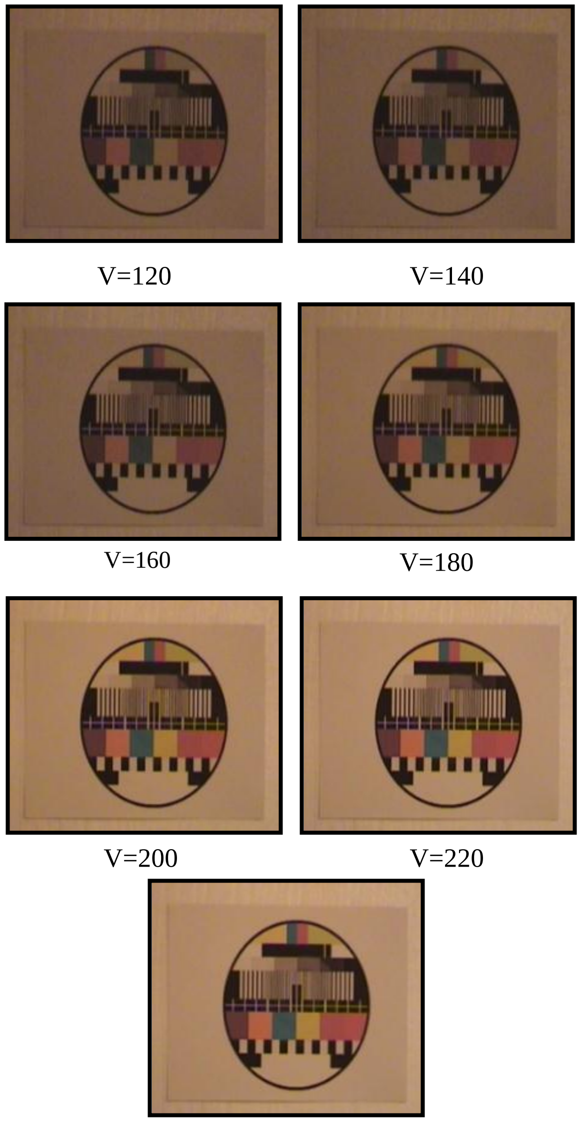



***Fig.(6) The images captured under different lighting conditions using left light source.***




V=240

***Follow Fig.(6) The images captured under different lighting conditions using left light source.***

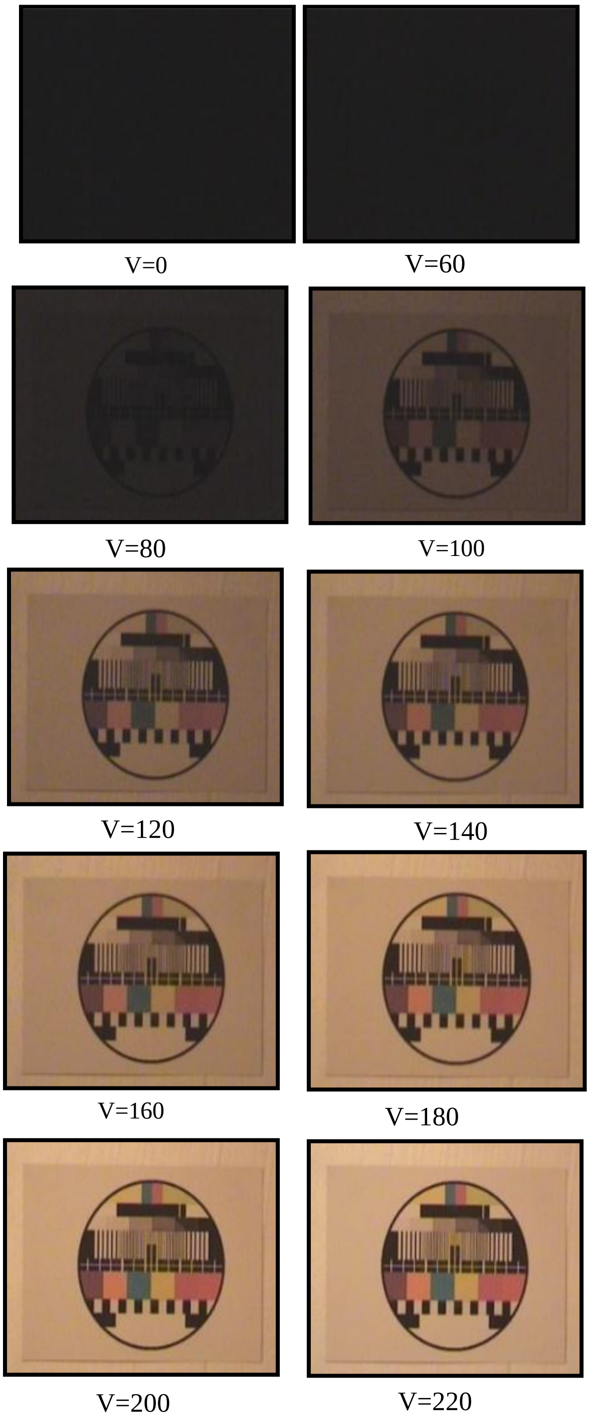
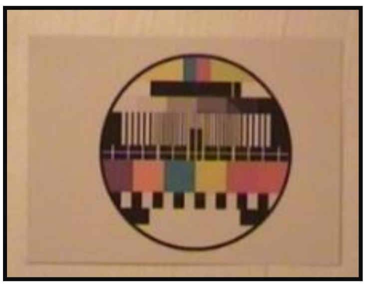



***Fig.(7) The images captured at different lighting conditions using right light source.***




***Follow Fig. (7) The images captured at different lighting conditions using right light source.***

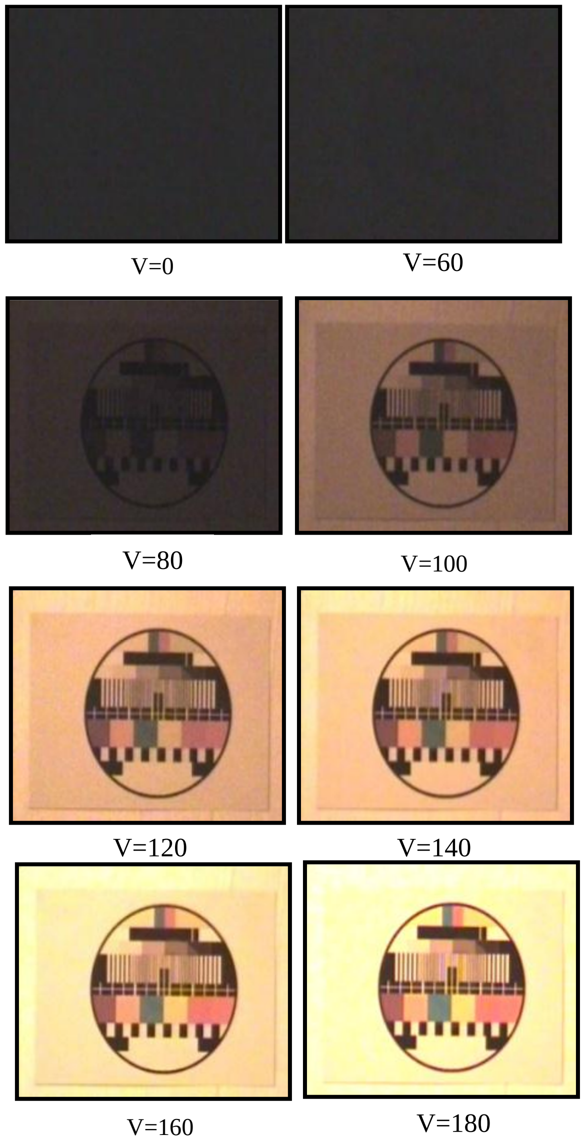
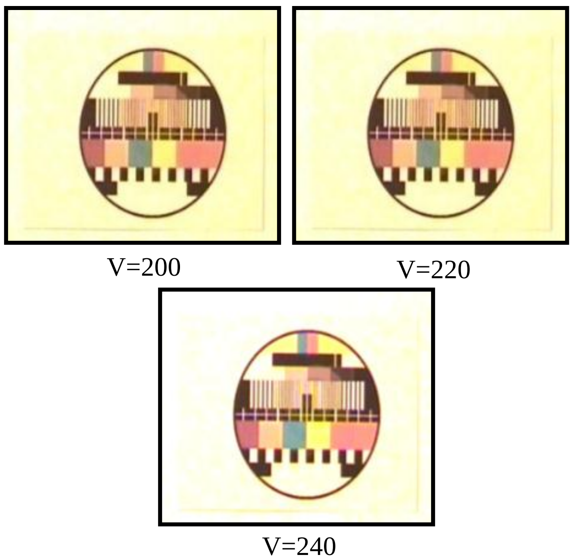



***Fig.(8) The images from the collection of image captured at different lighting system voltage (Light and left).***




***Follow Fig.(8) The images from the collection of image captured at different lighting system voltage (Light and left).***

## Result and Discussions

### Discussion Homogeneity of Illumination in the Imaging System

The homogeneity of illumination in the imaging system studied by extracting two horizontal lines from image pixels plane (one from top and anther from bottom) and extracting 2–vertical lines (one from the left and anther from right) of image pixels plane. These extracted lines from homogenous white image region. Then study these lines for the all captured images in different cases of intensity variations, and uniformity and non uniformity of lightness. The relation between voltage and lighting intensity of cut off line (top and bottom) linear relation and the relation was approximated to the nearest function applying the following relation (y= ax+ b). The values of the parameters (a, b) of cut off line different lightings (from right and Left side) were found.

The Figs. (9-10) show the relation between parameter a and voltage of cut off line (top and bottom). We note here that the parameter a value of lighting in the right side is decreasing while parameter a value of lighting in the left side is increasing. The Fig.(11) shows the relation between parameter b values of cut off and voltage in the right side. The relation between parameter b values of cut off and voltage in the right side has the same behavior except the difference in parameter b values. Hence, only the results of horizontal cut off in the right side were showed in the study. We note that parameter b values of cut off line will increase by increasing the voltage. Parameter a and b values may can be utilized to enhance images with different lightings.

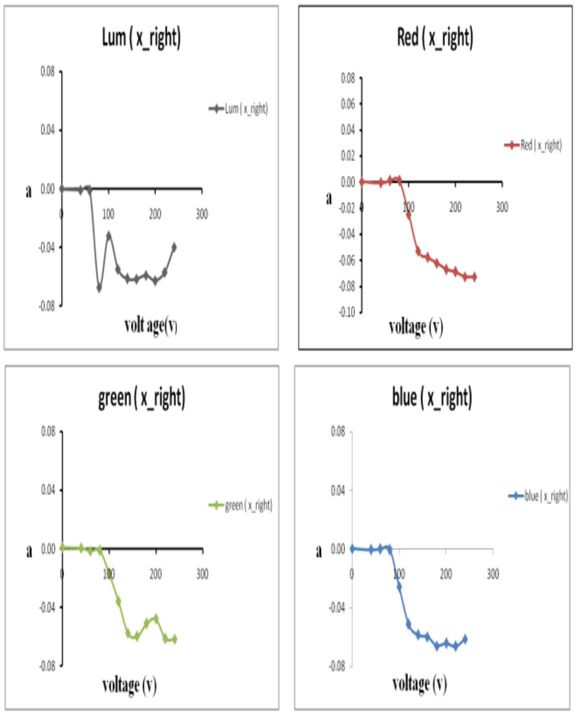
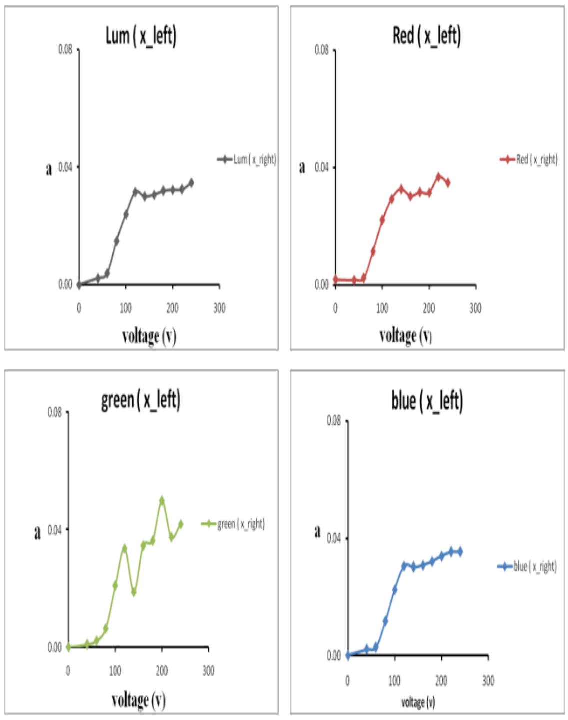



***Fig.(9) A-The relationship between estimated a parameter and the voltage of lightness to horizontal lines from left.***




***Follow Fig. (9) B- The relationship between estimated a parameter and the voltage of lightness to horizontal lines from right.***

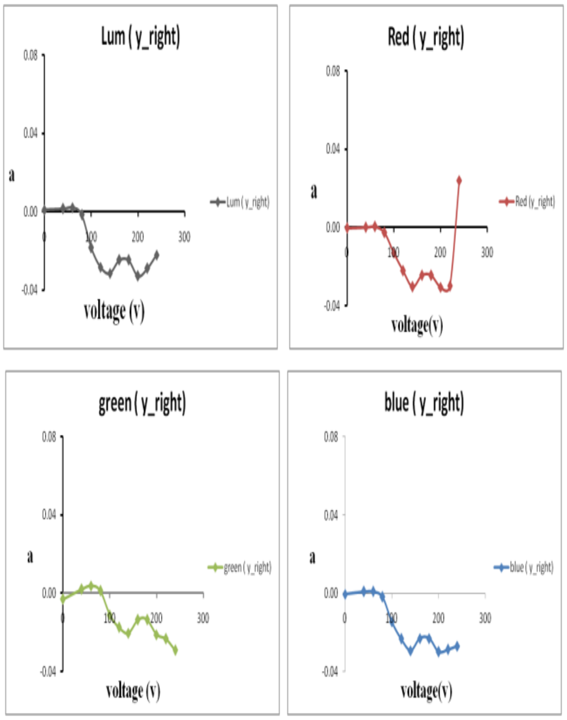
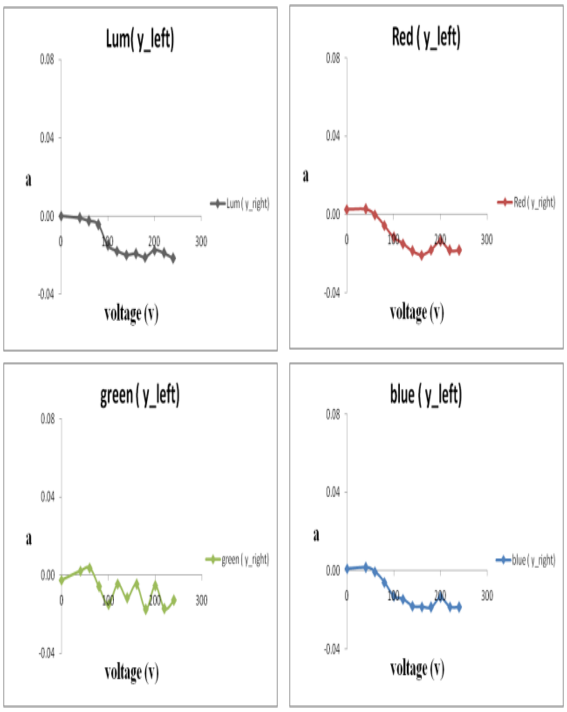



***Fig. (10) A-The relationship between estimated a parameter and the voltage of lightness to vertical lines.***




***Follow Fig.(10) B- The relationship between estimated a parameter and the voltage of lightness to vertical.***

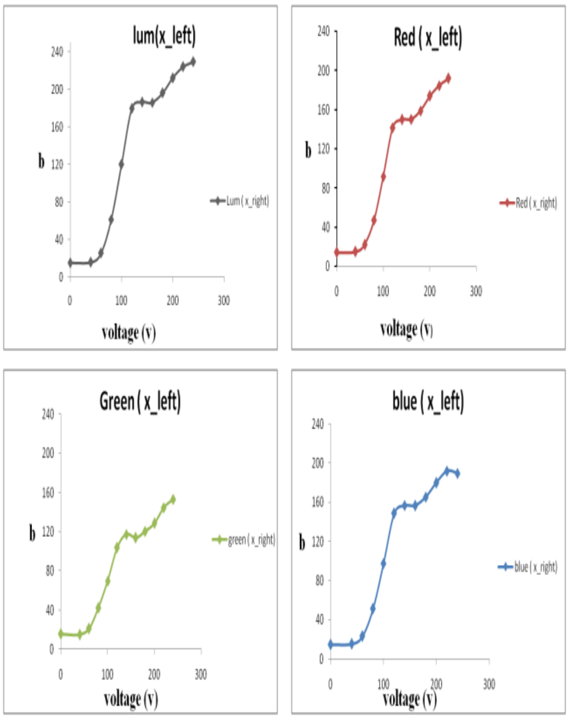



***Fig.(11) The value of intercept with coordinate of y parameter b as a function of the voltage of lightness systems (light from right).***

## Result of Retinex Image Enhancement Technique

The Retinex Image Enhancement Algorithm **is**

1. Input color image $I_i(x,y)$ , i= r,g,b .
2. Calculated Gaussian surrounds function

$$F(x,y,c_n) = (k)\exp\left(\frac{-(x^2 - y^2)}{c_n^{\ 2}}\right)$$

where $k$ is normalization constant, $c_n$, n=3, {$c1=250$, $c2=120$, $c3=80$}.

3. Computed SSR from $R_i(x,y,c) = \log[I_i(x,y)] - \log[F(x,y,c_n) \otimes I_i(x,y)]$ .

4. Computed MSR from

$$R_{MSR}(x,y,w,c) = \sum_{n=1}^{N} W_n R_i(x,y,c_n)$$

$N=3$ $\{w_1=w_2=w_3=1/3\}$.

5.Calculated MSR with color restoration by:

$$I_i'(x,y,a_1,b_1) = b_1 \log[1 + a_1 \frac{I_i(x,y)}{\sum_{i=1}^{3} I_i(x,y)}]$$

$b_1=100, a_1=125$.

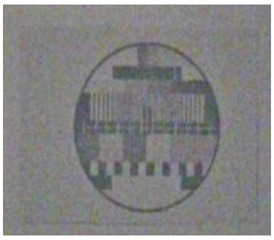
6. Output image getted form gain offset by $I_{pi}(x,y)=0.35(I_i'(x,y,a_1,b_1)+0.56)$.

Images resulted from programmed adding of captured images using lighting source at the right side only and captured images using lighting source at the left side only are shown in Fig.(12).

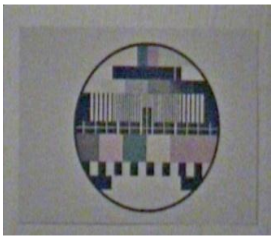
V=0

V=60

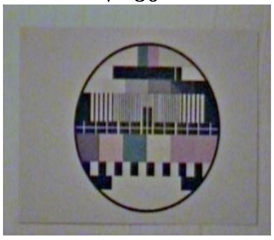
***Fig.(12) Mean of two images (left and right) applying retinx method.***



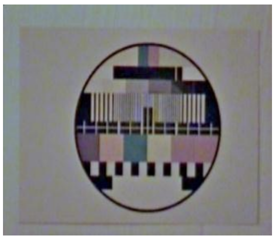
V=80



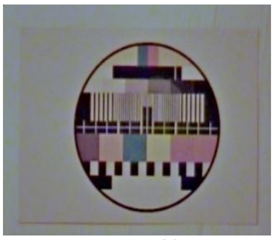
V=100



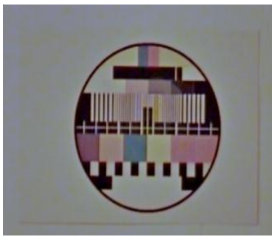
V=120



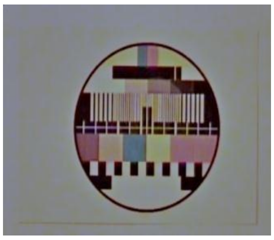
V=140



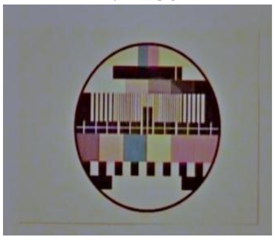
V=160



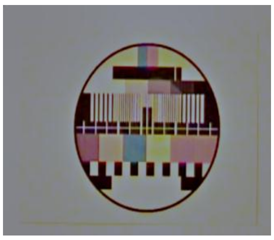
V=180



V=200



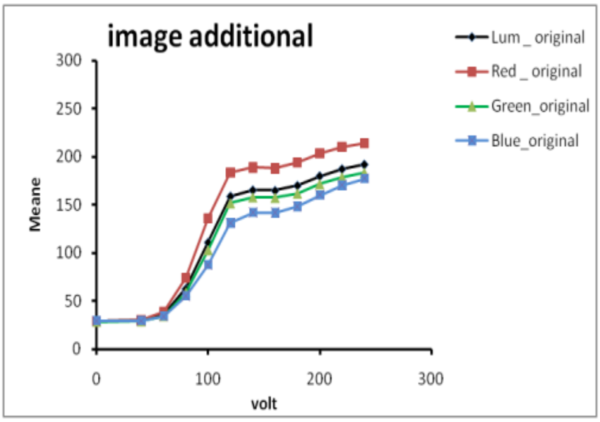
V=220



V=240

***Follow Fig.(12) Mean of two images (left and right) applying retinx method.***

Statistical characteristics mean (μ), standard deviation (σ) and general contrast (c) of modified images were calculated for the purpose of technique efficiency estimation. The statistical characteristics were drawn as function of imaging system voltage before and after using enhancement technique. They were shown in Fig.(13, 14) which shows that the best image after enhancement was that at V = 100 volts and general contrast values are maximum. By increasing the voltage, decrease in general contrast values are noticed although lighting intensity increased. Contrast value was higher at V = 100 volts, while mean values of images resulted after enhancement process were very approximate.



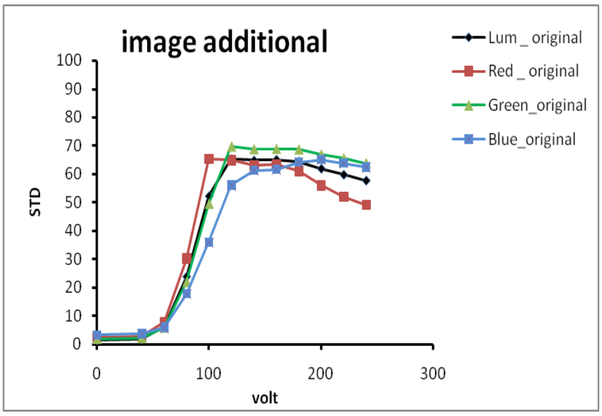
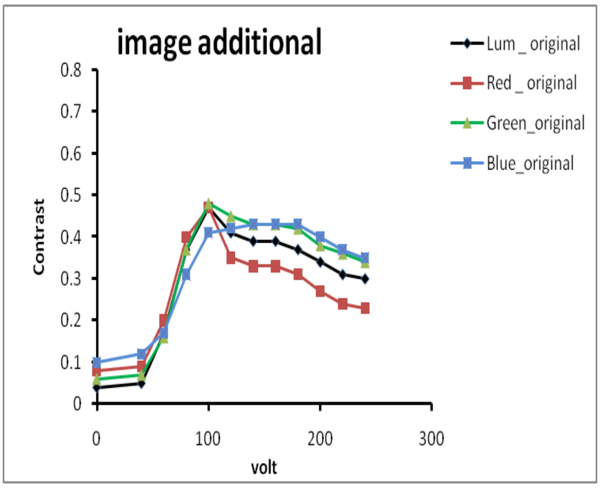




***Fig.(13) The Statistical properties (μ, σ, contrast ) for RGB and L-competent Before enhancement.***




*Follow Fig. (13) The Statistical properties (μ, σ, contrast ) for RGB and L- competent Before enhancement.*

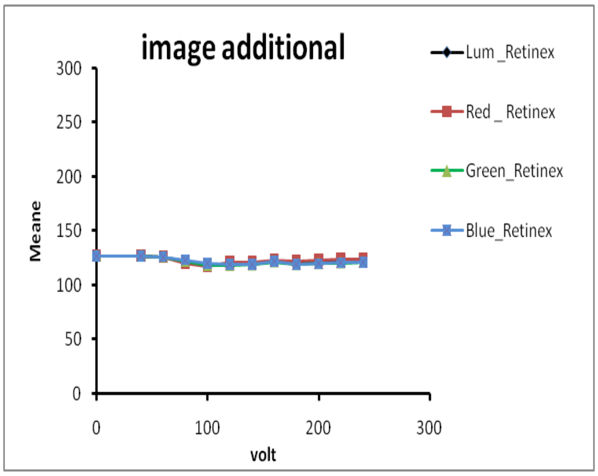
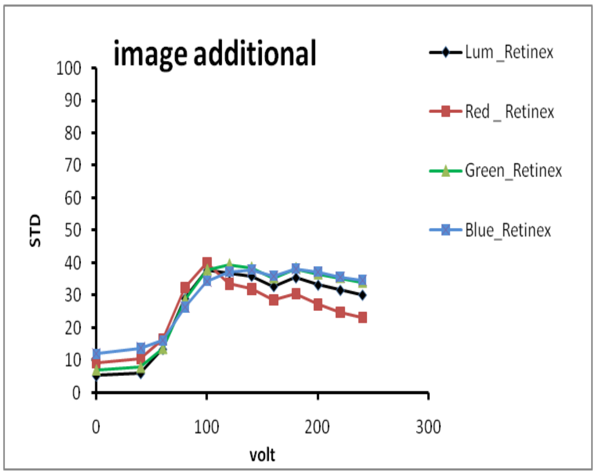
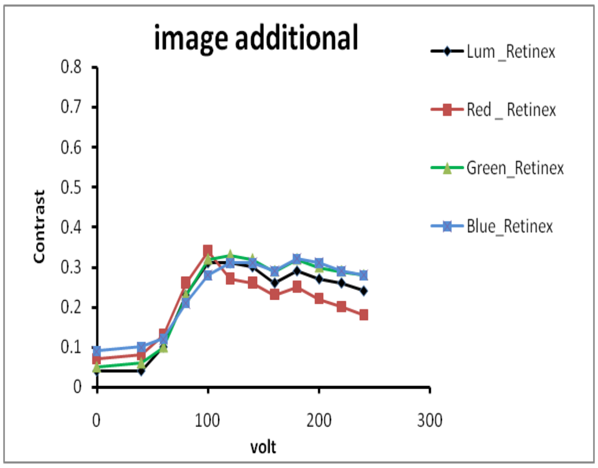



*Fig.(14) The Statistical properties (μ , σ, contrast ) for RGB and L-competent After enhancement by using method retinex.*




*Follow Fig.(14) The Statistical properties (μ , σ, contrast ) for RGB and L-competent After enhancement by using method retinex.*

## Conclusion

Retinex is an effective algorithm, as compared with other image enhancement techniques .The result show that the algorithm deal with images color with better results, and improves the image contrast, and the statistical properties (μ ,σ, contrast) for images enhancement are to maintain the general attributes of statistical properties of image with different lightings according the lighting intensity of imaging system .

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**الخلاصة**

في هذه الدراسة تم تطبيق خوارزمية retinex لتحسين الصور الملتقطة بشدة إضاءة غير متجانسة. يمكن لخوارزمية التحسين retinex أن تحسن تباين الصورة مقارنة بخوارزمية معادلة المخطط التكراري. حيث اظهرت نتائج البحث ان الصورة الناتجة من تقنية التحسين ذات تباين أفضل من تباين الصورة قبل التحسين، كما اظهرت نتائج البحث ان توزيع شدة الاضاءة لمصدر منظومة التصويرهي علاقة خطية مع الفولتية وتم تقريب الرسم الى دالة اقرب خط مستقيم حيث ان شدة الاضاءة لمصدر منظومة التصوير من جهة اليمين تتناسب عكسيا مع شدة الاضاءة من جهة اليسار للخط المستقطع من عرض وارتفاع الصورة الاختبارية، في هذه الدراسة تم حساب الخصائص الاحصائية للصور الملتقطة بشدة اضاءة مختلفة قبل وبعد استخدام تقنية التحسين حيث تم ملاحظة ان قيم التباين للصور بعد استخدام تقنية التسحسين يكون اقل مقارنة بقيم التبيابن قبل التحسين.