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Generalized Equilization Model for Camera Image Enhancement

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Abstract: In this Dissertation we develop joint algorithm on contrast enhancement and white balancing by correlating the effect of one parameter on other. If we work on one parameter other gets degraded, hence in image enhancement if one parameter is optimized, the enhancement result cannot be optimized. In this work, for the image, which are having low contrast due to insufficient light or chip quality of imaging sensor is focused. Contrast enhancement and white balancing is done in correlation with one another to get optim um image enhancement. In this dissertation a generalized equalization model for image enhancement has been developed. Based on the analysis of the relationships between image histogram contrast enhancement and white balancing, a generalized equalization model integrating contrast enhancement and white balancing into a unified framework of convex programming of image histogram is established. It shows that many image enhancement tasks can be accomplished by the focus model using different configurations of parameters. With two defining properties of histogram transform, namely contrast gain and nonlinearity, the model parameters for different enhancement applications can be optimized. Then an optimal image enhancement algorithm is implemented, that theoretically achieves the best joint contrast enhancement and white balancing result with trading-off between contrast enhancement and tonal distortion. Subjective and objective experimental results show favorable performances of the declare algorithm in applications of image enhancement, white balancing and tone correction. The comparison of Histogram Equalization (HE), Contrast limited Adaptive Histogram Equalization (CLAHE), Contrast Enhancement Using Brightness Preserving Bi-Histogram Equalization (BBHE) and Generalized Equalization Model for Image Enhancement (Proposed Method) is shown.
Index Terms—Contrast enhancement, contrast gain, generalized equalization, nonlinearity of transform, tone mapping, white balancing.

1. INTRODUCTION:

The fast advance of technologies and the prevalence of imaging devices, billions of digital images are being created every day. Due to undesirable light source, unfavorable weather or failure of the imaging device itself, the contrast and tone of the captured image may not always be satisfactory. Therefore, image enhancement is often required for both the aesthetic and pragmatic purposes. In fact, image enhancement algorithms have already been widely applied in imaging devices for tone mapping. For example, in a typical digital camera, the CCD or CMOS array receives the photons passing through lens and then the charge levels are transformed to the original image .

Usually, the original image is stored in RAW format, with a bit-length too big for normal displays. So tone mapping techniques, e.g. the widely known gamma correction, are used to transfer the image into a suitable dynamic range. More sophisticated tone mapping algorithms were developed through the years, just to name a few.

Generally, tone mapping algorithms can be classified into two categories by their functionalities during the imaging process.

1) White Balancing*:* Because of the undesirable luminance or the physical limitations of inexpensive imaging sensors, the captured image may carry obvious color bias.1 To calibrate the color bias of image, we need to estimate the value of light source, the problem of which called color constancy a suitable physical imaging model, one can get an approximated luminance, and then a linear transform can be applied to map the original image into an ideal one.

2) Contrast Enhancement*:* Contrast enhancement algorithms are widely used for the restoration of degraded media, among which global histogram equalization is the most well liked choice. Other variant includes local histogram equalization and the spatial filtering type of methods . In the fractional filter is used to promote the variance of texture so as to enhance the image. In a texture synthesis based algorithm is proposed for degraded media, such as old pictures or films. On the other hand, transform based methods also exist, e.g. curvelet based algorithm . In an adaptive steering regression kernel is make to combine image sharpening with denoising.

Despite of the abundant literature on image enhancement, including those representatives listed above, two challenging problems for image enhancement are still not solved.

MOTIVATION:

The images which are taken in low light does not give good appearance. To get good appearance of image, image must have good contrast and white balancing. The algorithm available either works on contrast enhancement or white balancing, but not on both. If algorithm of contrast enhancement is applied on image which disturbs white balancing and if white balancing algorithm is used, which disturbs the contrast of image. So there is limitation in using this algorithm. So to enhance image which is taken in low light, we have to go for contrast as well as white balancing also. But no algorithm gives justification to both enhancement parameter simultaneously, hence the algorithm which can give justification to both image enhancement parameter needs to be developed. Hence the algorithm is developed.

OBJECTIVE:

The objective of establishing the generalized equalization model includes:

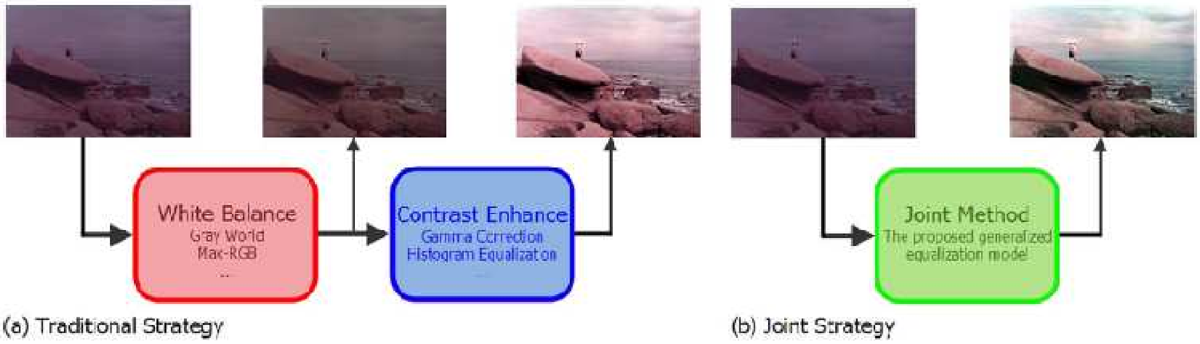
\1) Giving a unified explanation to white balancing problem and contrast enhancement problem.

2) Providing an explicit objective function for these two problems and proposing a joint algorithm for them.

3) Controlling the performance of the algorithm by as few parameters as possible.

BRIEF DESCRIPTION OF SYSTEM WORK:

The first step to achieve contrast enhancement while preserving a good tone**.** The contrast and tone of an image have mutual influence. Because of the complicated interaction, those algorithms merely aiming towards contrast enhancement or white balancing cannot provide optimal visual effect. Most, if not all, of current image enhancement systems divide white balancing and contrast enhancement into two separate and independent phases. This strategy has an obvious drawback: although tone has adjusted in the white balancing phase, contrast enhancement may undesirably bias it again. This trouble has been observed in many applications, e.g. the de-hazing algorithms in achieve contrast enhancement by



(a) Illustration of traditional image enhancement strategy. (b) Illustration of joint image enhancement strategy[15]

increasing saturation of the image, but cause tonal distortion in some cases. It is easy to imagine that joint white balancing and contrast enhancement, is a more efficient solution towards overall quality enhancement.

Different types of enhancement algorithms to each other are related therotically. In this aspect, the work in unifies spatial filtering based enhancement methods, including bi-lateral filter, non-local means filter, steering regression and so on, which has potential applications in image enhancement. However, the computational complexity of filtering based method is much higher than traditional histogram based method in most situations. In many cases, such as real-time video surveillance, the histogram based methods are still being widely used. Taking its significance in practical situations into consideration, finding a unified framework of

histogram based methods is a meaningful work that may bring more inspirations to the image enhancement problem and facilitate future research. Although being originated from different applications, both of contrast enhancement and white balancing are essentially tone manipulation processes. In fact, it is noticed that almost all global algorithms of contrast enhancement and white balancing are based on histogram transform. Recently, on the concept of low-level visual information. However, this unified model does not take contrast into consideration, so it is limited to the application of white balancing. A strict definition of expected context-free contrast and devised a method called Optimal Contrast-Tone Mapping (OCTM) to solve contrast enhancement problem by maximizing the expected contrast gain subject to an upper limit on tone distortion. OCTM is a promising solution for the intensity channel, but it does not elucidate the relationship between contrast and tone on the color channels.

In this dissertation I will analyze the relationships between image histogram and tone/contrast of image, and establish a generalized equalization model. We will propose a series of definitions for context-free contrast, tone distortion and its nonlinearity, and clarify their relationships in terms of different parameters in the unified model. The generalized equalization model amalgamates histogram-based tone mapping algorithms in a generalized framework of convex programming and therefore is a joint strategy as shown in Fig.(b). Experimental results show that the proposed method can be widely used in a series of enhancement applications with promising results.

2. LITERATURE REVIEW:

There are several applications in which image enhancement is required.

Several algorithms are developed by different researchers. The algorithms are developed according to types of images and the arena in which image enhancement is required. For image enhancement particular parameter needs to be considered as per requirement. Every algorithm is having its advantages and limitations. There is no particular measure for the image enhancement, only measure available is human aesthetic approach, hence there is no limitation for the image enhancement. Following are related work done by different researcher for the image enhancement.

Histogram equalization, which aims at information maximization, is widely used in different ways to perform contrast enhancement in images.

- **Automatic Exact Histogram Specification Technique:**

DebashisSenet[1] proposed an automatic exact histogram specification technique and used for global and local contrast enhancement of images. The desired histogram is obtained by first subjecting the image histogram to a modification process and then by maximizing a measure that represents increase in information and decrease in ambiguity. A new method of measuring image contrast based upon local band-limited approach and center-surround retinal receptive field model is also devised in this paper. This method works at multiple scales (frequency bands) and combines the contrast measures obtained at different scales using Lp-norm. In comparison to a few existing methods, the effectiveness of the proposed automatic exact histogram specification technique in enhancing contrasts of images is demonstrated through qualitative analysis and the proposed image contrast measure based quantitative analysis.

The majority of color histogram equalization methods do not yield uniform histogram in gray scale. After converting a color histogram equalized image into gray scale, the contrast of the converted image is worse than that of an 1-D gray scale histogram equalized image [1].

- **Novel 3-D Color Histogram Equalization:**

Ji-Hee Han, Sejung Yang[2] propose a novel 3-D color histogram equalization method that produces uniform distribution in gray scale histogram by defining a new cumulative probability density function in 3-D color space. Test results with natural and synthetic images are presented to compare and analyze various color histogram equalization algorithms based upon 3-D color histograms. Author also presents theoretical analysis for non-ideal performance of existing methods. Converted image is worse than that of an 1-D gray scale histogram equalized image.

- **Histogram Equalization (HE):**

TarikArici, SalihDikbas[3], has presented a general framework based on histogram equalization for image contrast enhancement. In this framework, contrast enhancement is posed as an optimization problem that minimizes a cost function. Histogram equalization isan effective technique for contrast enhancement. However, conventional histogram equalization (HE) usually results in excessive contrast enhancement, which in turn gives the processed image an unnatural look and creates visual artifacts. By introducing specifically designed penalty terms, the level of contrast enhancement can be adjusted; noise robustness, white/black stretching and mean-brightness preservation may easily be incorporated into the optimization. Analytic solutions for some of the important criteria are presented. Finally, a low-complexity algorithm for contrast enhancement is presented, and its performance is demonstrated against a recently method.

- **Novel Methodology for Contrast Enhancement:**

Dubok Park1, Minjae Kim2[4] proposed a novel methodology for contrast enhancement and noise reduction in very noisy data with low dynamic range on images captured by surveillance camera under extremely low light condition. For the initial noise reduction, a motion adaptive temporal filtering based on the Kalman filter is employed. Then, the denoised image is first inverted and subsequently dehazed as a tone mapping to enhance the visibility based on the observation that the inverted low light image presents quite similar characteristics to hazy image. Finally, the remaining noise is removed using the Non-local means (NLM) denoising step. The overall approach essentially transforms very dark images progressively into more visible form and effectively reduces the high intensity noise generated by the tone mapping process. From the experimental results, effectiveness of the proposed method is validated by comparing with the most recent and leading conventional method.

Bad weather, such as fog and haze, can significantly degrade the visibility of a scene. Optically, this is due to the substantial presence of particles in the atmosphere that absorb and scatter light. In computer vision, the absorption and scattering processes are commonly modeled by a linear combination of the direct attenuation and the air light. Based on this model, a few methods have been proposed, and most of them require multiple input images of a scene, which have either different degrees of polarization or different atmospheric conditions. This requirement is the main drawback of these methods, since in many situations, it is difficult to be fulfilled.

- **Automated Method:**

To resolve the problem, J.-P. Tarel and N. Hautiere[5] introduce an automated method that only requires a single input image .This method is based on two basic observations: first, images with enhanced visibility (or clear-day images) have more contrast than images plagued by bad weather; second, air light whose variation mainly depends on the distance of objects to the viewer, tends to be smooth. Relying on these two observations, we develop a cost function in the framework of Markov random fields, which can be efficiently optimized by various techniques, such as graph-cuts or belief propagation. The method does not require the geometrical information of the input image, and is applicable for both colour and gray images.

Mages of outdoor scenes are usually degraded under bad weather conditions, which results in a hazy image. To date, most haze removal methods based on a single image have ignored the effects of sensor blur and noise.

- **Three-Stage Algorithm for Haze Removal:**

Xia Lan1, Liangpei Zhang2[6], a three-stage algorithm for haze removal, considering sensor blur and noise, is proposed. In the first stage, Author preprocesses the degraded image and eliminates the blur/noise interference to estimate the hazy image. In the second stage, we estimate the transmission and atmospheric light by the dark channel prior method. In the third stage, a regularized method is proposed to recover the underlying image. Experimental results with both simulated and real data demonstrate that the proposed algorithm is effective, based on both the visual effect and quantitative assessment.

Contrast enhancement has an important role in image processing applications. Conventional contrast enhancement techniques either often fail to produce satisfactory results for a broad variety of low-contrast images, or cannot be automatically applied to different images, because their parameters must be specified manually to produce a satisfactory result for a given image [6].

- **New Automatic Method for Contrast Enhancement:**

Z. Chen, B. Abidi, D. Page, and M. Abid[7] introduce a new automatic method for contrast enhancement is described. The basic procedure is to first group the histogram components of a low-contrast image into a proper number of bins according to a selected criterion, then redistribute these bins uniformly over the gray scale, and finally ungroup the previously grouped gray-levels. Accordingly, this new technique is named gray-level grouping (GLG). GLG not only produces results superior to conventional contrast enhancement techniques, but is also fully automatic in most circumstances, and is applicable to a broad variety of images. An extension of GLG, selective GLG (SGLG), and its variations is discussed in the paper. SGLG selectively groups and ungroups histogram components to achieve specific application purposes, such as eliminating background noise, enhancing a specific segment of the histogram.

While in the continuous case, statistical models of histogram equalization/specification would yield exact results, their discrete counterparts fail. This is due to the fact that the cumulative distribution functions one deals with are not exactly invertible. Otherwise stated, exact histogram specification for discrete images is an ill-posed problem. Invertible cumulative distribution functions are obtained by translating the problem in a K–dimensional space and further inducing a strict ordering among image pixels.

- **Computational Photography Techniques:**

D. Coltuc, P. Bolon and J.-M. Chassery [8] the proposed ordering refines the natural one. Experimental results and statistical models of the induced ordering are presented and several applications are discussed: image enhancement, normalization, watermarking, etc.

Many recent computational photography techniques decompose an image into a piecewise smooth base layer, containing large scale variations in intensity, and a residual detail layer capturing the smaller scale details in the image. In many of these applications, it is important to control the spatial scale of the extracted details, and it is often desirable to manipulate details at multiple scales, while avoiding visual artifacts.

- **Edge-Preserving Multi-Scale Image Decompositions:**

Z. Farbman, R. Fattal, D. Lischinski[9] introduces a new way to construct edge-preserving multi-scale image decompositions. Author shows that current base detail decomposition techniques, based on the bilateral filter, are limited in their ability to extract detail at arbitrary scales. Instead, Author advocates the use of an alternative edge-preserving smoothing operator, based on the weighted least squares optimization framework, which is particularly well suited for progressive coarsening of images and for multi-scale detail extraction. After describing this operator, Author shows how to use it to construct edge-preserving multi-scale decompositions, and compare it to the bilateral filter, as well as to other schemes. Finally, Author demonstrates the effectiveness of our edge-preserving decompositions in the context of LDR and HDR tone mapping, detail enhancement, and other applications.

- **Novel System:**

J. K. et al., "Deep[10] introduce a novel system for browsing, enhancing ,and manipulating casual outdoor photographs by combining them with already existing geo referenced digital terrain and urban models. A simple interactive registration process is used to align a photograph with such a model. Once the photograph and the model have been registered, an abundance of information, such as depth ,texture, and GIS data, becomes immediately available to our dissertation .This information, in turn, enables a variety of operations, ranging from dehazing and relighting the photograph, to novel view synthesis, and overlaying with geographic information. Author describes the implementation of a number of these applications and discusses possible extensions. Author's results show that augmenting photographs with already available 3D models of the world supports a wide variety of new ways for us to experience and interact with our every day snapshots.

- **Estimating the Optical Transmission in Hazy Scenes:**

R. Fattal, "Single image dehazing[11] presents a new method for estimating the optical transmission in hazy scenes given a single input image. Based on this estimation, the scattered light is eliminated to increase scene visibility and recover haze-free scene contrasts. In this new approach we formulate a refined image formation model that accounts for surface shading in addition to the transmission function. This allows us to resolve ambiguities in the data by searching for a solution in which the resulting shading and transmission functions are locally statistically uncorrelated. A similar principle is used to estimate the color of the haze. Results demonstrate the new method abilities to remove the haze layer as well as provide a reliable transmission estimate which can be used for additional applications such as image refocusing and novel view synthesis .

- **Brightness Preserving Histogram Specification Methods**

Different from the methods presented in the previous section, this section presents a set of works which aim at improving contrast while preserving the brightness of the image. Chen and A. Ramli [12] proposed a novel extension of BBHE referred as Minimum Mean Brightness Error Bi – Histogram Equalization (MMBEBHE) to provide maximum brightness preservation. BBHE separates the input image's histogram in to two based on input mean before equalizing them independently. In MMBEBHE, the separation is based on the threshold level which would yield Minimum Absolute Mean Brightness Error (AMBE).

3. PROPOSED WORK:

Analysis:

The images which are taken in low light have not give good appearance. To get good appearance of image, image must have good contrast and white balancing. The algorithm available either works on contrast enhancement or white balancing, but not on both. If algorithm of contrast enhancement is applied on image which disturbs white balancing and if white balancing algorithm is used, which disturbs the contrast of image. So there is limitation in using these algorithm. So to enhance image which is taken in low light, we have to go for contrast as well as white balancing also. But no algorithm gives justification to both enhancement parameter simultaneously, hence the algorithm which can give justification to both image enhancement parameter needs to be developed.

4. PROBLEM DEFINATION:

White balancing is a popular image enhancement method, with a critical step of color constancy. The linearity of the transform is the most significant feature of histogram-based white balancing algorithm. Linearity is also an important difference between white balancing and contrast enhancement. The performance of histogram equalization is not optimal in most situations. The essential reason for its limited performance is, the questionable assumption that the histogram of ideal image obeys uniform distribution. To get better equalization result, we need to find a better distribution, which is a big challenge. A common feature of all the enhancement methods mentioned above is that the transform of histogram is non-linear.

Non-linearity of histogram transform is the biggest problem in image enhancement using white balancing and contrast enhancement.

To get the solution over the problem we propose joint algorithm for them using Generalized Equalization Model.

FEASIBILITY STUDY:

The image taken in low light, suffers from low level contrast which results in dull image. To convert that image into good quality image, Enhancement must be done. For this several algorithms are developed. But no algorithm gives justification for white balancing and contrast enhancement simultaneously. Here offer algorithm which gives justification to both parameters simultaneously. The algorithm is feasible for the images which are having low contrast due to insufficient light. If the algorithm is applied for good quality image, it disturb the quality of image.

Design:

Consider ,

$\mathbf{f} = (f_r, f_g, f_b)^T$ The available dynamic range of is f_c is $[0, L_c]$, $c = r, g, b$,

The histogram of image is denoted as $\{\mathbf{h}_c, \mathbf{p}_c\}_{c=r,g,b}$,

Here, $\mathbf{h}_c \in R^K$ represents the total K intensity levels, which corresponds to probability vector $\mathbf{p}_c \in R^K$,

K is the number of intensity level whose probability value is non-zero,

Given the histogram of original image, denoted as , $\{\tilde{\mathbf{h}}_c, \mathbf{p}_c\}_{c=r,g,b}$,

we achieve image enhancement by manipulating the histogram to be $\{\hat{\mathbf{h}}_c, \mathbf{p}_c\}_{c=r,g,b}$,

The distance between adjacent intensity levels is denoted as, $s_{ck} = h_{ck} - h_{c,k-1}$, $k = 2, \ldots, K$, $s_{c1} = h_{c1}$.

According to this denotation, we have , $\tilde{\mathbf{s}}_c = \nabla\tilde{\mathbf{h}}_c, \hat{\mathbf{s}}_c = \nabla\hat{\mathbf{h}}_c$. ∇ . represents derivation operator.

Histogram-Based Analysis on White Balancing :

White balancing is a popular image enhancement method, with a critical step of color constancy. Being different from the learning based methods in, we focus on a low-level approach to color constancy and establish the relationship between color constancy and the histogram of and image.

In the Lambertian surface model, the image is expressed as

$$f_c = \int r(\lambda) l(\lambda) m_c(\lambda) d\lambda. \quad \text{………………….(1)}$$

Here, λ is the wavelength of visible light. $r(\lambda)$ is the surface reflectance, $l(\lambda)$ is the light source, and $m_c(\lambda)$ is the sensitivity of camera in the channel . The goal of color constancy is to estimate the projection of light source on the RGB space. To achieve this goal, many assumptions have been made. For example, the max-RGB is proposed in , which estimates the light source from the maximum responses of the three channels. Another widely used assumption is gray-world hypothesis [13], which assumes that the average reflectance in the scene is achromatic. Recently, these assumptions are unified in [14], as follows

$$\left(\frac{\int |\mathbf{f}(\mathbf{x})|^{\alpha} d\mathbf{x}}{\int d\mathbf{x}}\right)^{\frac{1}{\alpha}} = C\mathbf{e}. \quad \text{……………(2)}$$

Here, **x** is the coordinate of pixel. **C** is an arbitrary positive constant and α is a parameter. $\mathbf{e} = [e_r, e_g, e_b]^T$ is the normalized estimation of light source. When $\alpha = 1$ (2) is equivalent to Gray-world assumption while when $\alpha = \infty$ (2) is equivalent to max-RGB. White balancing is achieved by multiplying the element of **e** to the corresponding channel of **f** . Because $[1/\sqrt{3}, 1/\sqrt{3}, 1/\sqrt{3}]^T$ is the normalized form of white light, the multiplication factor of channel **c** is $1/e_c\sqrt{3}.$.

From the viewpoint of image histogram, the left side of (2) can be rewritten as

$$\left(\frac{\int |\mathbf{f}(\mathbf{x})|^\alpha \, d\mathbf{x}}{\int d\mathbf{x}}\right)^{\frac{1}{\alpha}} = \begin{pmatrix} \left(\mathbf{p}_r^T \mathbf{h}_r^\alpha\right)^{\frac{1}{\alpha}} \\ \left(\mathbf{p}_g^T \mathbf{h}_g^\alpha\right)^{\frac{1}{\alpha}} \\ \left(\mathbf{p}_b^T \mathbf{h}_b^\alpha\right)^{\frac{1}{\alpha}} \end{pmatrix},$$

…… …………(3)

Where, $\mathbf{h}_c^\alpha = [h_{c1}^\alpha, \ldots, h_{cK}^\alpha]^T.$ Eq. (3) reveals the interconnection among white balancing and histogram. Given an image, **e** is calculated as

$$e_c(\alpha) = \frac{\left(\mathbf{p}_c^T \tilde{\mathbf{h}}_c^\alpha\right)^{\frac{1}{\alpha}}}{\sqrt{\sum_{c=r,g,b} \left(\mathbf{p}_c^T \tilde{\mathbf{h}}_c^\alpha\right)^{\frac{2}{\alpha}}}}.$$

………………(4)

As a result, the histogram of white balancing result, denoted as h_c , is computed as follows

$$\hat{\mathbf{h}}_c = \frac{1}{e_c(\alpha)\sqrt{3}} \tilde{\mathbf{h}}_c.$$

………………(5)

It is obvious that this process is linear. The linearity of the transform is the most significant feature of histogram-based white balancing algorithm. In the next subsection, we will show that this linearity is also an important difference between white balancing and contrast enhancement.

Histogram-Based Analysis on Contrast Enhancement

In the expected context-free contrast of image is defined by

$$\mathbf{C} = \mathbf{p}_c^T \mathbf{s}_c.$$

……………..(6)

By the definition, the maximum contrast is L_c , which is achieved by a binary black-and-white image; the minimum contrast is zero when the image is a constant. So, the contrast enhancement is achieved by maximizing (6) in, as follows.

$$\hat{\mathbf{s}}_c = \arg\max_{\mathbf{s}_c} \mathbf{p}_c^T \mathbf{s}_c,$$
$$s.t. \quad \sum_{i=1}^{K} s_{ci} = L_c, \quad s_{ci} \geq d,$$

………(7)

where the first constraint makes sure that the output image still has a suitable dynamic range and the second constraint denotes the minimum distance between adjacent gray levels as **d.**

However, although the definition in (6) has obvious statistical meaning, it is not optimal to be used as objective function directly. Eq. (7) is a linear programming problem whose solution is sparse—to the maximum probability p_{ci}, the corresponding $\hat{s}_{ci} = L_c - d(K-1)$, and other $\hat{s}_{ck} = d.$. Realizing this problem, another two constraints are added in to suppress artifacts, which make the model complicated and sensitive to some predefined parameters.

Before the work in , histogram-based algorithm has been widely used in contrast enhancement. The most commonly used approach is histogram equalization , which makes the probability density function of enhanced image close to that of uniform distribution. After equalization, the ith intensity level of new image, $\hat{h}_{ci}$, is

$$\hat{h}_{ci} = C \sum_{j=0}^{i} p_{cj}.$$

…………….(8)

Here, **C** is a constant. Eq. (8) also gives a relationship between histogram and the distance between adjacent intensity level, as following shows.

$$\hat{s}_{ci} = \hat{h}_{ci} - \hat{h}_{c,i-1} = C p_{ci}.$$

……….(9)

According to (8), (9), histogram equalization is equivalent to solving following optimization problem.

$$\hat{\mathbf{s}}_c = \arg\max_{\mathbf{s}_c} \frac{1}{\left\|\mathbf{P}_c^{-1}\mathbf{s}_c\right\|_\infty}, \quad s.t. \quad \sum_{i=1}^{K} s_{ci} = L_c, \quad s_{ci} \geq d.$$

……………………..(10)

Here, $\mathbf{P}_c = diag(p_{c1}, \ldots, p_{cK})$. ,

The performance of histogram equalization is not optimal in most situations. The essential reason for its limited performance is the questionable assumption that the histogram of ideal image obeys uniform distribution. To get better equalization result, we need to find a better distribution which is a big challenge. Recently, some adaptive histogram equalization methods are proposed but gave neither a clear definition of contrast nor an explicit objective function of contrast enhancement like (7), (10) shows. A common feature of all the enhancement methods mentioned above is that the transform of histogram is non-linear, which is different from white balancing.

The aims of establishing the generalized equalization model include: 1) giving a unified explanation to white balancing problem and contrast enhancement problem; 2) providing an explicit objective function for these two problems and proposing a joint algorithm for them; 3) controlling the performance of the algorithm by as few parameters as possible. The proposed model is inspired by (7), (10). Although (7),(10) seem to be very different, if we regard the order of P_c and the norm of the objective function as two parameters, and , (7), (10) are rewritten in a generalized form:

$$\hat{\mathbf{s}}_c = \arg\max_{\mathbf{s}_c} \frac{1}{\left\|\mathbf{P}_c^{-\beta}\mathbf{s}_c\right\|_n}, \quad s.t. \quad \sum_{i=1}^{K} s_{ci} = L_c, \quad s_{ci} \geq d.$$

……(11)

Both (10) and (7) have interesting relationships with (11).When $n = 2$ and $\beta = 0.5$ (or $n = \infty$ and $\beta = 1$) maximum is reached when $s_{ci}/(p_{ci})^\beta = C$, which is equivalent (10). When $n = 2$ and $0 \leq \beta < 0.5$ (or $n = \infty$ and $0 \leq \beta$, the solution would be smoother than that of (10). When $n = 1$ or $\to \infty$, the solution is equivalent to that of (7). Compared with traditional histogram equalization, (11) is more flexible, because the target histogram does not have to obey uniform distribution. Considering the fact that traditional histogram equalization often leads to over-enhanced results, relaxing the constraints of uniform distribution can suppress over-enhancement effectively. On the other hand, as long as $n > 1$and β in the suitable range, histogram of the enhanced image can avoid to be too sparse. As a result, we do not need additional constraints like OCTM does.

According to the analysis above, (11) provides a reasonable and unified definition with the objective function of contrast enhancement. We will further take white balancing into the model. Based on (4), (11), we formulate the generalized equalization model mathematically as follows.

$$\hat{\mathbf{s}}_c = \arg\min_{\mathbf{s}_c} \sum_{c=r,g,b} \left\|\mathbf{P}_c^{-\beta}\mathbf{s}_c\right\|_n ,$$
$$s.t. \quad \sum_{i=1}^{K} s_{ci} = \frac{1}{e_c(\alpha)\sqrt{3}} \sum_{i=1}^{K} \tilde{s}_{ci}, \qquad s_{ci}$$

………..(12)

Here, $\tilde{\mathbf{s}}_c$ is the original distance between adjacent intensity levels of the channel c . In generalized model, we set the upper bound L_c as the result of white balancing $1/e_c(\alpha)\sqrt{3}\sum_{i=1}^{K}\tilde{s}_{ci}$.

On the top of (12), we introduce two measures into generalized equalization model: the gain of expected context-free contrast and the nonlinearity of the transform from $\tilde{\mathbf{h}}_c$ to $\hat{\mathbf{h}}_c$, which are defined as

$$\mathbf{G} = \frac{\mathbf{p}_c^T\hat{\mathbf{s}}_c}{\mathbf{p}_c^T\tilde{\mathbf{s}}_c}, \quad \mathbf{NL} = \left\|\nabla(\hat{\mathbf{s}}_c - \tilde{\mathbf{s}}_c)\right\|_2 .$$

…….(13)

If $\tilde{\mathbf{s}}_c$ is homogeneous enough $\mathbf{NL} \approx \|\nabla\hat{\mathbf{s}}_c\|_2$, . The larger NL , the stronger nonlinearity of the transform. The nonlinearity of white balancing methods is close to 0. On the other hand, the contrast enhancement methods often have strong nonlinearity, which achieve visible enhancement of contrast. However, separate nonlinear transform of histograms of three channels may cause tone distortion. In the next section, we will theoretically prove that the proposed method, with a suitable configuration of parameters, can achieve a best trade-off between contrast enhancement and tone adjustment.

Following table indicates the meaning of symbols used in model

TABLE I
THE LIST OF IMPORTANT VARIABLES IN THE MODEL

Variables	Descriptions
$\tilde{\mathrm{h}} \in R^K$	The intensity levels of original image
$\hat{\mathrm{h}} \in R^K$	The intensity levels of enhanced image
$\tilde{\mathrm{s}} \in R^K$	The distance of adjacent intensity levels of original image
$\hat{\mathrm{s}} \in R^K$	The distance of adjacent intensity levels of enhanced image
$\mathrm{p} \in R^K$	The probability of intensity level
$\mathrm{P} \in R^{K\times K}$	The diagonal matrix of p
L	The upper bound of intensity
d	The lower bound of distance
$\mathrm{e}(\alpha)$	The estimated light source for original image
α	The parameter of color constancy
β	The parameter of nonlinearity
n	The parameter of norm
G	Contrast Gain
NL	Nonlinearity of transform

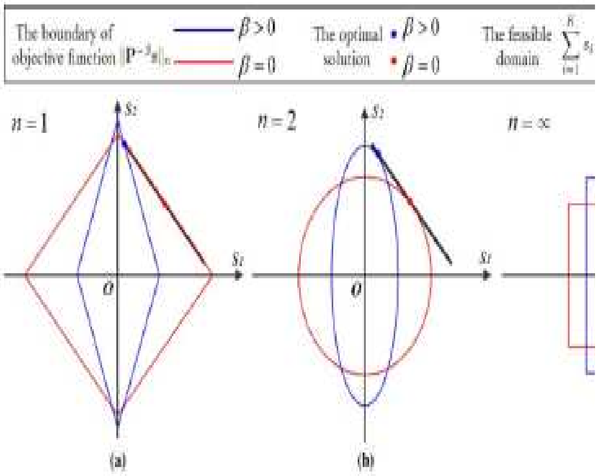


Fig. In each sub-figure, the thick black line represents the feasible domain of Eq. (12); the red and blue wireframes show the boundaries of the objective function of Eq. (12) which correspond to the $\beta = 0$ and $\beta > 0$ situations respectively; the red and blue points are the optimal solutions corresponding to the $\beta = 0$ and $\beta > 0$ situations respectively. The parameter in (a), (b), (c) is 1, 2 and ∞ respectively.

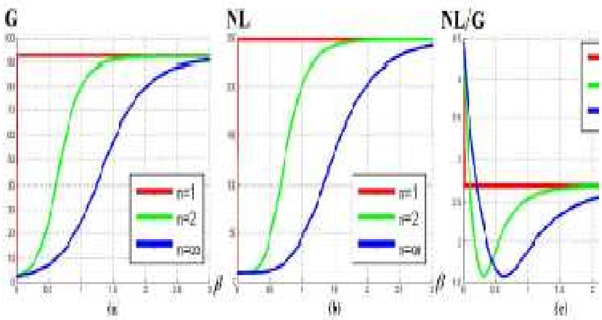


Fig. . Figure (a) gives the curves of contrast gainwith the increase of . Figure (b) gives the curves of nonlinearity of transform with the increase of β . Figure (c) gives the curves of the ratio of NL_n to G_n ,n=1,2,.∞ . The red, green and blue curves corresponding to n=1,2,….∞, respectively.

SYSTEM ALGORITHEM:

1. Input Camera image **f** = (fr, fg ,fb)T
2. Separate image in three intensity matrices R,G,B
3. Find out histogram of three intensity matrices {hc,pc}c=r,g,b .
4. Calculate intensity levels of three matrices.
5. Calculate average distance between adjacent intensity levels as per equation 12.
6. Find out area of concentration of pixel intensities.
7. If the pixels are concentrated in particular region of intensity, spread out the pixel concentration throughout the available intensity levels as per distance criteria in 12.
8. Apply the adjustment parameter to spread out the pixel concentration throughout the available intensity levels.
9. Check the quality of image by combining three intensity matrices R, G, B.
10. Apply the white balancing parameter to the image.
11. Tune the adjustment parameter by small fractional value and go to 8 for 1st iteration only.
12. Check the quality of image before and after fine tuning, if the quality of image after tuning is better go to 11 else 13.
13. Consider last but one image as enhanced image.

In the above algorithm decision maker is the user only. User can decide the quality of image by his visual aesthetic approach.

SYSTEM IMPLEMENTATION & TESTING:

To implement proposed algorithm we use matlab software with image processing toolbox. Here we achieve image enhancement by using four methods

1)Histogram Equalization

2) Contrast limited Adaptive Histogram Equalization (CLAHE)

3) Contrast Enhancement Using Brightness Preserving Bi-Histogram Equalization (BBHE).
4) Generalized Equalization Model for Image Enhancement (Proposed Method).

For the first two methods available function in the matlab is used is used which are "histeq"(HE) and "adapthisteq" (CLAHE).

Both functions are used to work on single matrix. But the color image comprised of three matrix for three color coordinate i.e. RGB. Here we apply the both algorithm to image by separating all three matrices and achieved the result of image enhancement.

Syntax and description for the "histeq"(HE) is given below

imhist(I)
imhist(I, n)
imhist(X, map)
[counts,x] = imhist(...)

Description

imhist(I) displays a histogram for the image I above a grayscale colorbar. The number of bins in the histogram is specified by the image type. If I is a grayscale image, imhist uses a default value of 256 bins. If I is a binary image, imhist uses two bins.

imhist(I, n) displays a histogram where n specifies the number of bins used in the histogram. n also specifies the length of the colorbar. If I is a binary image, n can only have the value 2.

imhist(X, map) displays a histogram for the indexed image X. This histogram shows the distribution of pixel values above a colorbar of the colormap map. The colormap must be at least as long as the largest index in X. The histogram has one bin for each entry in the colormap.

[counts,x] = imhist(...) returns the histogram counts in counts and the bin locations in x so that stem(x,counts) shows the histogram. For indexed images, imhist returns the histogram counts for each colormap entry; the length of counts is the same as the length of the colormap.

Syntax and description for the "adapthisteq" (CLAHE). is given below

J = adapthisteq(I)
J = adapthisteq(I,param1,val1,param2,val2...)

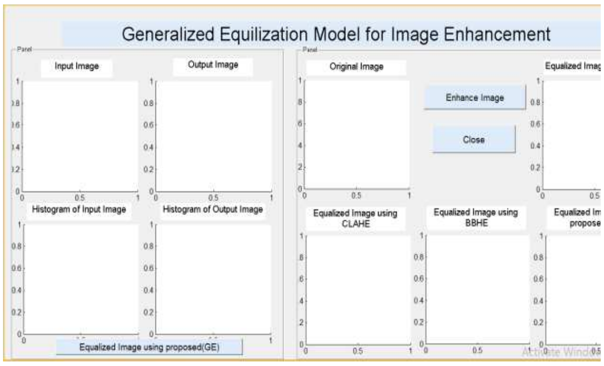
Description

J = adapthisteq(I) enhances the contrast of the grayscale image I by transforming the values using contrast-limited adaptive histogram equalization (CLAHE).

CLAHE operates on small regions in the image, called *tiles*, rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image.

J = adapthisteq(I,param1,val1,param2,val2...) specifies any of the additional parameter/value. Parameter names can be abbreviated, and case does not matter.

The algorithm for BBHE and Proposed method is developed. The matlab codes are written for it. The overall system is linked with the help of GUI. Which viewed as follows.



1.GUI Screen

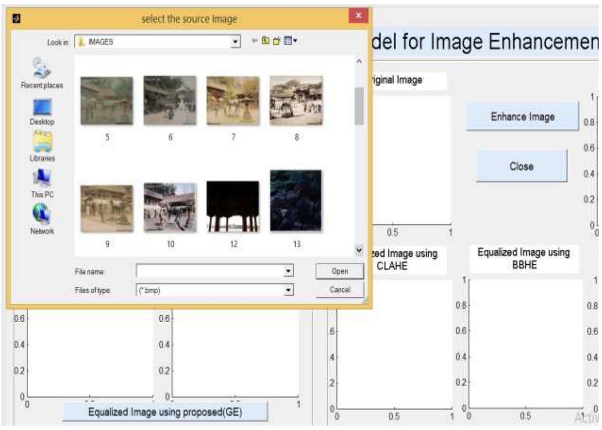
The GUI is divided in to two parts in the first part indicate input image and enhancement of image using proposed method. With their histogram. Second part indicate five images

1) Original image (Input Image)
2) Enhanced image by Histogram Equalization.
3) Enhanced image by CLAHE
4) Enhanced image by BBHE
5) Enhanced image by Generalized Equalization Model.

For the operation of GUI, three pushbuttons are provided

1) Equalized Image using Proposed(GE)
2) Enhance Image
3) Close

When we click first button, it takes us to select image as

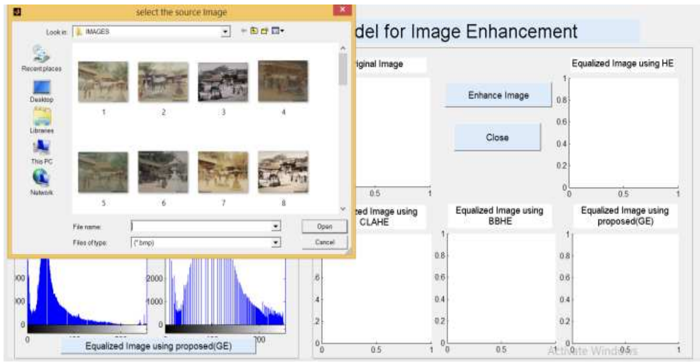


2.Select Screen

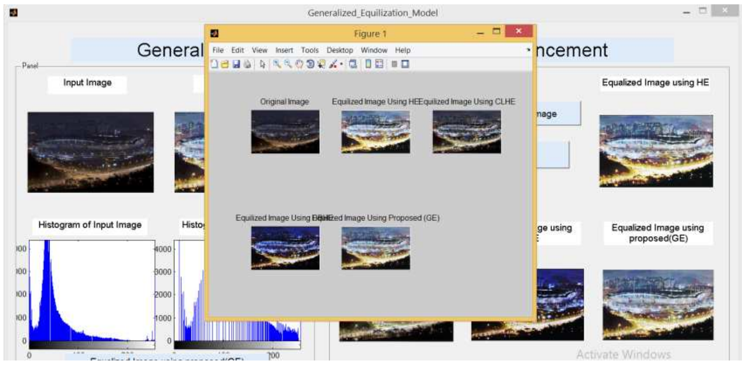
Select any image from the any folder or from any drive. We get the result as.

$\tilde{s}_c$ is the original distance between adjacent intensity levels of the channel c

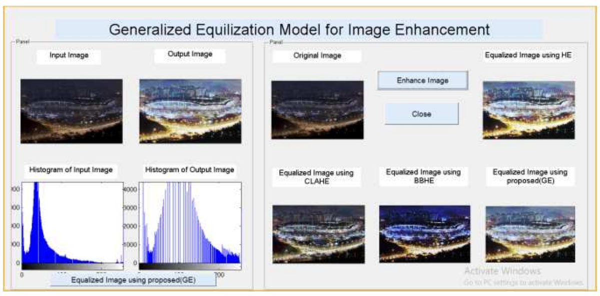
The we can see result for all algorithm by clicking second key "Enhance Image". When we click "Enhance Image" key we get following view.



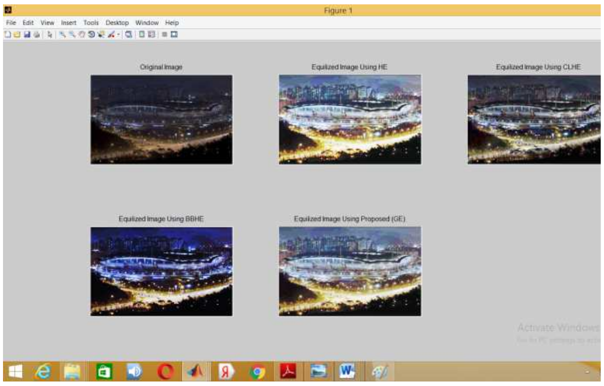
Then we can select any image and we get result as.



We can minimize this snapshot And get view as



If we compare result of all algorithms, we found the image enhancement by Generalized Equalization model is better for most of the images. To view more detail result we can view Figure 1 by maximizing it as.



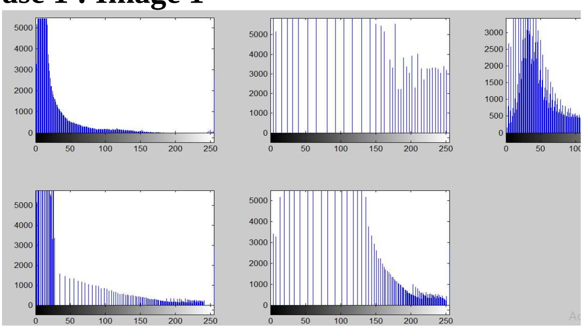
3.Output Screen

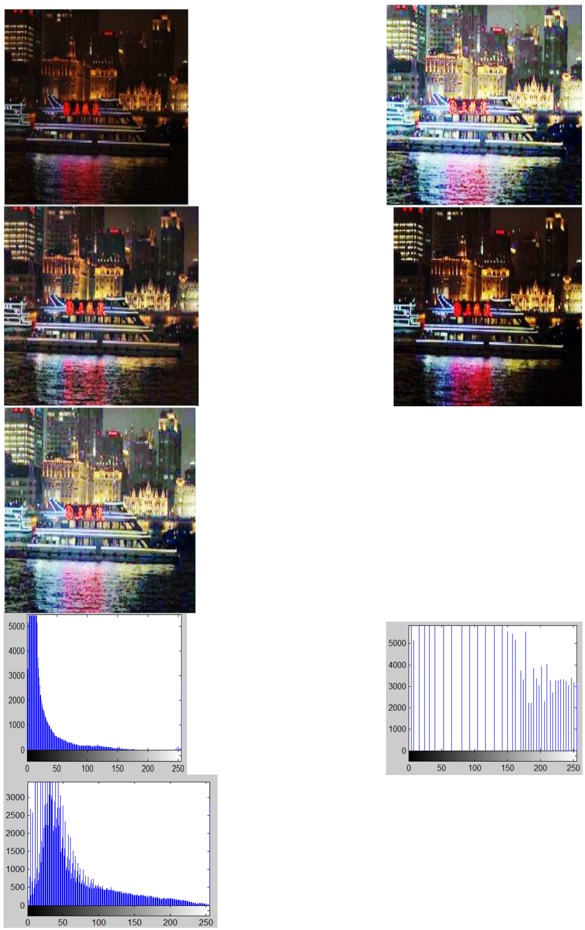
RESULT:

While taking image light source is not sufficient, hence in the image light intensity is very less. On this image four image Enhancement algorithms are mentioned,

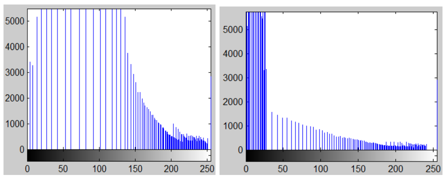
A. Original Image
B. Images enhanced by HE
C. Images enhanced by CLAHE
D. Images enhanced by BBHE
E. Images enhanced by GE (Proposed)

Case 1 : Image 1





A B C



D E

While taking image light source is not sufficient, hence in the image light intensity is very less. On this image four image Enhancement algorithms are applied

1st and 3rd image shows the histogram of the image. 1st and 3rd images are same, only in the 1st image viewing of histogram image is larger for better view.

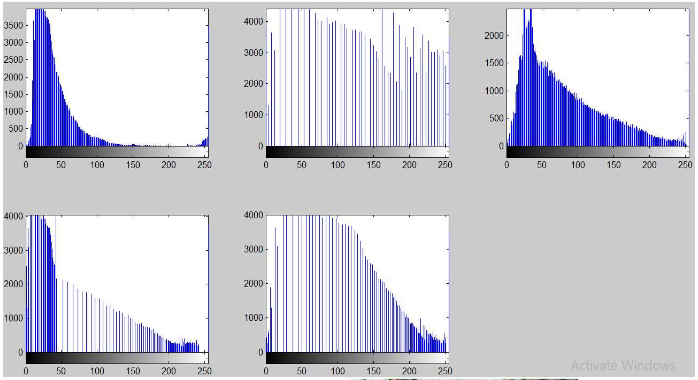
1) Image A indicates the image with low contrast as histogram indicates most of the pixesl are concentrated in the low light intensity area. Hence the image looks very dark.
2) Image Enhancement by HE

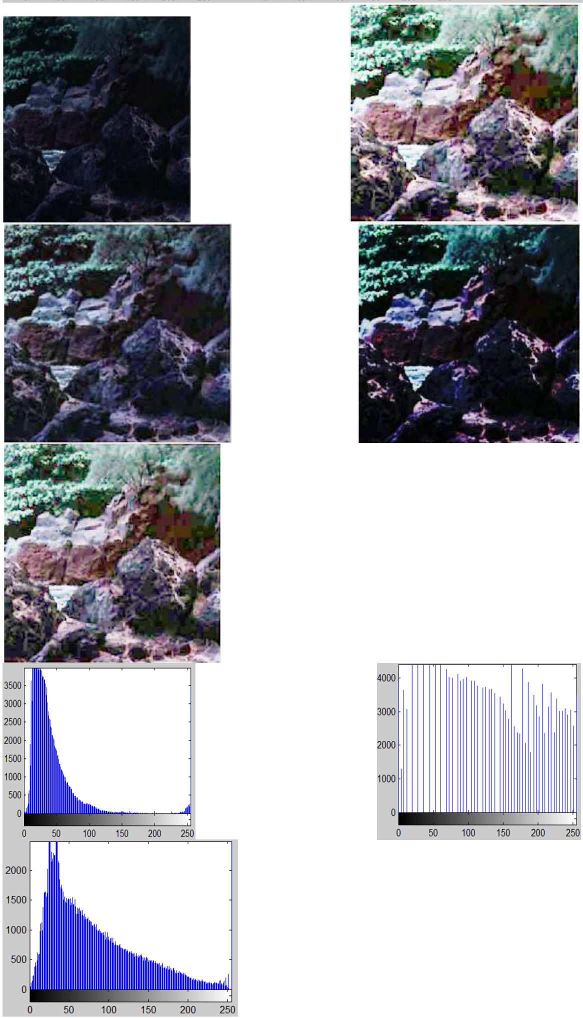
After enhancing the image, image view and its histogram indicates, the contrast enhancement of image is very good, but with that white effect in the image is also more.

3) Image Enhancement by CLAHE
Histogram of the Image indicates contrast of image is enhanced very slightly. The available color scale is not utilized completely. If we look at the image esthetic quality of image it is improved than the original one.

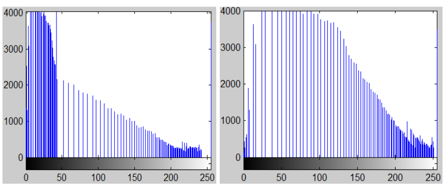
4) Image Enhancement by BBHE
Histogram of image indicates that darker region pixel intensities are not changed up to remarkable level. But the medium level intensities are assigned remarkable values. But total available color intensities are not used.
Contrast enhancement of image by this algorithm is very less. The algorithm does not affect the whiteness in the image.

5) Image Enhancement by Generalized Equalization model.
Histogram of the image indicates that available color intensities are used. HE also used available color intensities. But in HE image light estimation is not considered hence intensities are assigned by average estimation i.e. lowest intensity pixel in the image has assigned the lowest intensity level i.e.0. And highest intensity pixel assigned with highest intensity level i.e.255. All other pixel assigned with average intensity values in between. As in GE the intensities are assigned to pixel by considering the average light estimation in the image. Histogram also indicates the same.





A **B** **C**



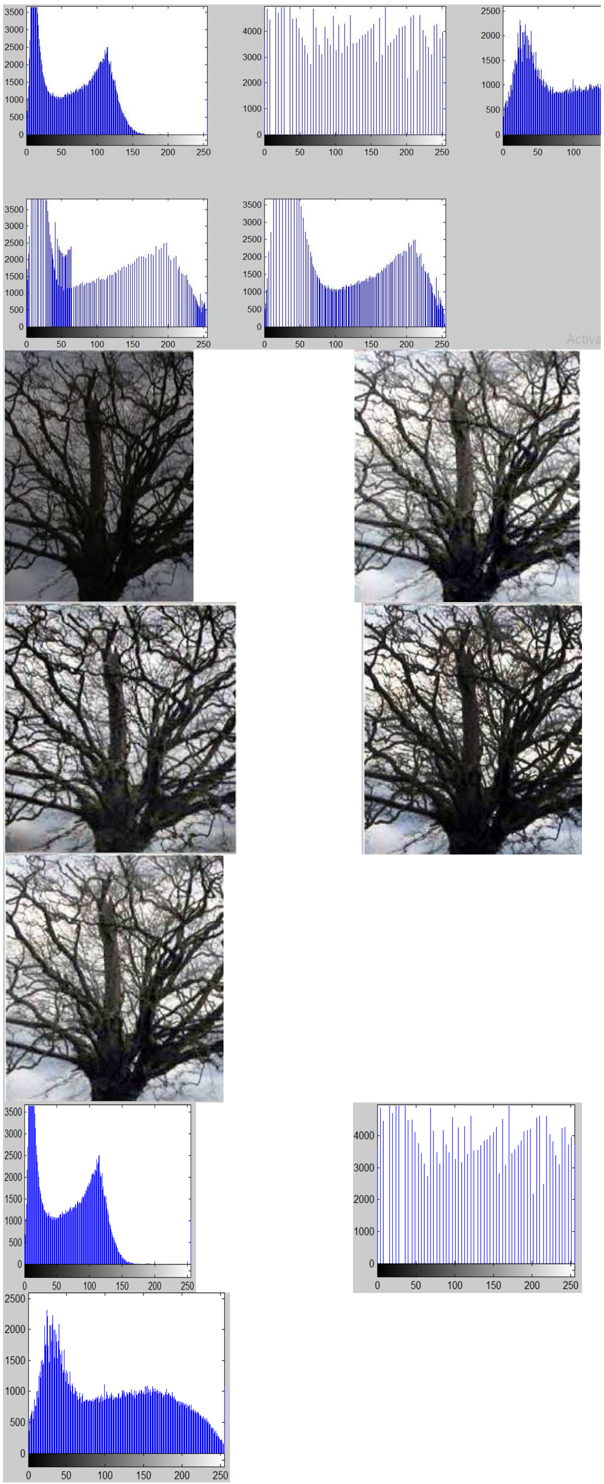
D **E**

Case 2: Image 2

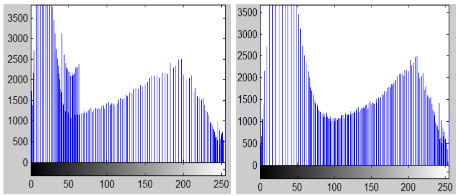
In this image, Image contrast is low due to imaging sensor.

If we compare the images image enhancement by proposed method look good.

Case 4: Image 4



A B C



D **E**

1) Image A indicates the image with low contrast as histogram indicates most of the pixesl are concentrated in the low light intensity area. Hence the image looks very dark.
2) Image Enhancement by HE
   After enhancing the image, image view and its histogram indicates, the contrast enhancement of image is very good, but with that white effect in the image is also more.
3) Image Enhancement by CLAHE
   Histogram of the Image indicates contrast of image is enhanced very slightly. The available color scale is not utilized completely. If we look at the image esthetic quality of image it is improved than the original one.
4) Image Enhancement by BBHE
   Histogram of image indicates that darker region pixel intensities are not changed up to remarkable level. But the medium level intensities are assigned remarkable values. But total available color intensities are not used.
   Contrast enhancement of image by this algorithm is very less. The algorithm does not affect the whiteness in the image.
5) Image Enhancement by Generalized Equalization model.
   Histogram of the image indicates that available color intensities are used. HE also used available color intensities. But in HE image light estimation is not considered hence intensities are assigned by average estimation i.e. lowest intensity pixel in the image has assigned the lowest

intensity level i.e.0. And highest intensity pixel assigned with highest intensity level i.e.255. All other pixel assigned with average intensity values in between. As in GE the intensities are assigned to pixel by considering the average light estimation in the image. Histogram also indicates the same.

CONCLUSION:

In this project we develop Generalized Equalization Model of image enhancement for the image which are having low contrast due to insufficient light, and made the comparison among four image enhancement algorithms Histogram equalization, Contrast Limited Adaptive Histogram Equalization(CLAHE), Brightness preserving Bi-Histogram Equalization (BBHE) and Generalized Equalization (GE) Model. The first three algorithms either work on either contrast enhancement or white balancing but not on both. GE algorithm works on both parameters, hence image enhanced by GE gives good visibility and appearance.

Thus the conclusion is when compared histogram and images enhanced by all four algorithms.

Image enhancement by HE gives very good contrast enhancement, but with that white effect in the image is also more. Hence image enhanced by HE looks brighter and whiter than any other image which degrades the esthetic look of image.

Image enhanced by CLAHE looks good but it is having low contrast. Whiteness of image enhanced slightly. Hence visibility of the darker region is less, as compare to another algorithm.

Contrast enhancement of image by BBHE algorithm is very less. The algorithm does not affect the whiteness in the image. If we look at the esthetic quality of image, individual opinion may vary between the image enhanced by CLAHE and BBHE.

Contrast enhancement by generalized equalization algorithm is good. If we compare image enhancement by HE and GE, The image enhanced by HE is whiter than image enhancement by GE. Esthetic quality of image is good compared with other images.

The algorithm gives good contrast enhancement as well as it controls the whiteness of the image. Hence the image quality looks good when image is enhanced by this algorithm.

FUTURE SCOPE:

In this dissertation, we analyzed the relationships between image histogram and contrast/tone. We established a generalized equalization model for global image tone mapping. Extensive experimental results suggest that this proposed method has good performances in many typical applications including image contrast enhancement, tone correction, white balancing and post-processing of de-hazed images.

In the future, besides global image enhancement, we expect to unify more local image enhancement methods into the model through local image feature analysis.

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