LOW-ILLUMINATED IMAGE ENHANCEMENT USING FUSION BASED LOG-TRANSFORM, CLAHE AND DEHAZING TECHNIQUES

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Abstract:
Image enhancement is among the foundation steps used in digital image processing with intention of getting a convenient and appropriate output than the original images. With the rise of demand in computer vision technology, the vision industry works on various application for gathering and restoring of the information, for example: industries related to productions, medical image processing, video surveillance, transportation industries, etc. As all information capture in real time; it behaves differently with respect to the amount of light presence in that surroundings i.e. outdoor situation while the key light (sun) is absent, with window light at indoor, or the picture click with only one source of light in a large space. Again in such condition captured images may have issues like containing high noise, colour imbalance, over enhancement or under enhancement and also may result in loss of information. Again in this era of information, we can't afford loss of information, so tends to these problem, low illuminated images need to be treated so that an enhanced output image is formed.

This paper propose a method based on reflectance-illumination model using adjusted log-transformation for details retrieval and brightness enhancement followed by CLAHE method used to control the oven enhancement and provide support to local enhancement. Also it undergoes under a Dehazing method for producing a dynamic and enhanced output. Proposed method uses the principle of single image fusion based method for enhancing the low illuminated images with objective of details retrieval and brightness enhancement simultaneously. We also focus on controlling the over enhancement.

Keywords: *Fusion Based Method, Log-Transformation, CLAHE, Dehazing, Brightness Enhancement, Contrast Management.*

1. INTRODUCTION

If the light is insufficient at any surface, any images click at this condition by camera can be reducing the quality of images; as the improper amount of light is entered to the camera sensory part from those current surroundings. This may result in degraded images, i.e. dark or low-light images with impairment, in which it is difficult to observe the real colour composition of the images and also difficult to understand full details from these images that is to collect the real data from that surrounding as required to us. Again as per rapid demand of vision technology digital image processing and its different techniques attract the attention of different industries and being used in several of them which need real-time images for fulfilment of their purpose. Commercial manufacturing, surveillance camera, smart freight, remote satellite monitoring, medical Industry and military applications are some example of these industries. In these field data loss cost in serious problems, because these industry highly depend on exact information. However as per the surroundings at the time of image captured some unwanted effects may noticed due to low light such as low illumination, low contrast and high noise. This results in loss of information from any image.

Image enhancement is an important preliminary stage in the field of image processing that has the mechanism to reconfigure the image in such a way that the output image is better than the original one with better colour distribution and with maximum details. Again clearing darkness and collecting the needed details from an images are very crucial tasks in the area like medical image processing, object hunting, object details extraction, face recognition, facial expression recognition, as these are facing problems like low illumination. Therefore, enhancement is most demanded application for these areas. Because of which, the technology to enhance an image have been emerged in a regular manner. Enhancement of any image deals to various aspects of images, such as darker zone, noisy factors, light contortion, texture details, colour consistency, etc. it is to be sure, by eliminating darker areas ameliorate image quality. Even so, it is to be keeping in mind while designing any enhancement techniques that the proposed method not only treat the darker pixels of images, but also retrieve the real and required details from the image. As defective image is a result of maximum impairments, so it is not justifying to working on only one factor among them. That is any enhancement method must not focus on a single problem of images as image degradation cause by several problem so it is very hard to treat each of them using a single method. So before implementing a method we must consider different aspects of our problem and its solution as well.

There are various method used for image enhancement. It can be classified in two broad sections that is Local Enhancement and Global Enhancement. The local Enhancement method enhances the smallest details of the image. Several local enhancement methods are introduced and utilized. Sometimes it enhanced the noise factor within the image which is an unwanted event in image enhancement.

Again Global Enhancement is another popular method in the sector of enhancement technique; it is mainly focus to overall details of the image unlike local enhancement. Mostly used methods among these methods is Histogram Equalization (HE), the prime objective behind this is to redistribute the intensity value while keeping the histogram dynamic. This proposed methods works in a proper manner but fails to delivered best result while it came to deal with local data.

1.2 Motivation and Problem Statement:

As discuss earlier, images taken in low illumination conditions may undergoes through different problem such as low brightness, noise and loss of information which is not recommended for any real life tasks. They are not eye catching and hamper the original information of the image. So for that reason brightness enhancement and detail retrieval is a much necessary task. And also it is challenging in nature for keeping the details unchanged while enhancing the brightness. Various enhancement algorithms proposed which are ending with loss of information or over/under enhancement. This becomes the main motivation behind this topic for us.

1.3 Objective of Research:

The main objectives of the paper are as follows:
1. Brightness Enhancement of the low-light image.
2. Prevent over-enhancement of the image.
3. Details Preservation and retrieval of maximum hidden details from a low luminance component.

The organisation of this paper is as follows that in first section it gives a brief idea about the enhancement techniques and it need to the society, also it clear the objective of the paper, second section cover different method used for enhancement in recent time and also about those method which are in practice yet, third method proposed the methodology used to resolve the problem occur due to low illumination , fourth section gives a details idea about the experiment conducted upon this and the result of experiment in both qualitative and quantitative analysis, and lastly fifth section give the conclusion.

2. RELATED METHODS

2.1. Gray Level Transformation:

Gray level transformation is direct approach upon the pixels. This involves 256 levels of gray scale in a histogram, horizontal axis represents a range of from 0 to 255, and the intensity values represents by vertical axis. This achieves by manipulating the gray values of images with another gray value. The basic formula:

$$s = T * r \qquad (1)$$

Where s refer to the pixel values both the (resultant and input value) T represents transformation, r represents the value of pixels; s refers to the pixel value before and after processing.

Furthermore this classified by 3 parts: Linear Transformation and Logarithmic Transformation, Power-Law Transformation.

2.2 Histogram Equalization:

A histogram of an image is the graphical representation of pixel intensity values. Histogram Equalization is an enhancement method that is applied with the intention of contrast adjustment of an image by using its histogram. To enhance the contrast of the images, the pixel values must be spread out most frequently or stretch the intensity range of the image. By performing above activity, this method allows the image areas with lower contrast to gain a higher contrast. On this basis the histogram equalization used the cumulative distribution function (CDF) to make changes in the result and also to have a probability density function that responsible for a consistent distribution; this is the way to, extract the hidden details from dark areas, and also the input image is going to be effectively enhanced [1].

Again as an increment model to this HE method, different methods are developed gradually. Those are: AHE (Adaptive Histogram Equalisation), CLAHE (contrast Limit Adaptive Histogram Equalization), DSIHE (Dualistic Sub-Image Histogram Equalisation), MMBEBHE (Minimum Mean Brightness Error Bi-Histogram Equalization), BPBHE (Brightness Preserving Bi-Histogram Equalization), etc.

2.3 Frequency Domain Method:

Gradually frequency domain methods are evolved where frequency domain is used as a key factor for enhancing an image [2]. As, digital images are initially in spatial domain so it needs to converted into frequency domain at initial steps. This method used different filters to enhance the input images. Again frequency domain method categories in two methods such as: (1) homomorphic Filtering (HF) and (2) wavelet transform (WT).

2.4 Retinex Methods:

This method mainly deals with colour images where this based upon the perceptual experience of colour and manipulating the colour variables and its related factors [3]. The gist behind this is to separate the reflected element from the images and treating this to get the enhancement by elimination different luminance effect, it may be high or low, from the images.

As per this, the human eye processes details of environment, when the light firstly incident upon the object and reflects the same information to the eye, human eye can see that object and able to distinguish about different colour. This depends on various uncertain factors which cannot be control by us, such as the intensity of the light source and intensity of luminance of light [4][5].

This illumination-reflection model, an image F(must be a 2D image[m,n]) is the product another two 2-D component such as R(Reflectance) and I(illumination) of the image.

$$F(m, n) = R(m, n) * I(m, n) \quad (2)$$

Here *m* represents the value of X –Axis and *n* represent the Y-axis. Retinex method again developed into single scale ratinex model, multi scale ratinex model, etc.

2.5 Fusion Based Methods:

Fusion based enhancement method [7]. In this method maximum details are collected from different images of same scene and get synthesize in a single high quality image to get a improved and enhanced output with maximum information.

Fusion based method again divided into different types as per the fusion they follow, such as: fusion based on background highlighting; basically this method deals by merging of two images low luminance images with proper luminance images (daytime), that the details from day time will be preserved and the background from low light we integrate to the daytime image so that we get the enhanced output at same background with all details. Fusion based on multiple exposure; this processes involve combining of multiple images of same scene. Fusion based on single image; this process involves the details extraction from the same image and enhancing them and so on.

3. METHODOLOGY

3.1 Brightness Enhancement:

Brightness is a purely subjective component of an image, deals with the reflectance of an image; this is observed with the visual perception. If the brightness factor is low, the image seems as dark in nature, and when brightness factor is high, the colour is clearer or brighter in nature. When the image has clearer colour than the image reflects more details as compare to the dark images.

So brightness enhancement is the important factor in low illuminated images to get or retrieve more details from the image also we have to check for over enhancement so that details must not be hampered. Brightness enhancement can be easily done by using non-linear transformation such as Log-transformation.

3.2 Framework of Proposed Method

The whole framework based on a simple illumination-reflectance model. Basically an image is a product of its illumination, which is the amount of source light incident on the scene and its reflectance, which is the amount of light reflected by the object in that scene. The mathematical expression for this method is as follows:

$$F(m,n) = I(m,n) * R(m,n) \quad \text{........(3)}$$

Where $F(m,n)$ is the two-dimensional function deals with formed image or output image, this is the composition of $I(m,n)$ and $R(m,n)$, illumination and reflectance respectivly.

If I factor on a scene is evenly distributed in the space, then the illumination seems to be uniform in nature and the captured image F gives a satisfactory output. However, if I is uneven within the surroundings of image then we may comes with two different situations with this unevenness of illumination.

Firstly, the portion with greater I value of an image is over enhanced and secondly, the portion with lower I value termed as under exposed or low light image. The second stage result in a fuzzy image where details of images are not clearly visible and information of the image is hidden as the illumination in that image is low. So, by separating I from F, this paper can treat the effects of uneven illumination of a image, which leads us to reach our objective of brightness enhancement and details preservation [8].

3.2.1 Work flow of Proposed Fusion Method

In persuade to the above theory, we proposed such a framework to separate the illumination factor or luminance factor from the image and enhances it, so that we get a better output image and also able to achieve our prime objective of brightness enhancement and details retrieval, This framework involves Log-transformation over luminance component to improve the illumination ratio over each pixel, which is achieve by eliminating the association among the RGB colour components by modifying them, that is the image is transformed into YUV colour space where we can get luminance component Y, which followed by contrast limit adaptive histogram equalisation (CLAHE) for controlling the over-enhancement factor which may produced by log transformation and after that luminance factor Y get merged with chrominance factor U,V . Than a histogram of the output image to be consider to find the treated image is dynamic of not and then enter to the dehazing phase to reduce halo effects and to make the image dynamic.

3.2.2 YUV Color Space

The YUV colour space defines one luminance component (Y) means physical linear-space brightness, and other two are U and V (the chroma's). RGB(Red, Green, Blue) is a very complex, In RGB image illumination-reflectance model cannot be used so easily as RGB has high bandwidth. This limitation makes this paper to use YUV colour-spaces. YUV having a low bandwidth with similar feature provide a convenient environment to execute the illumination-reflectance model efficiently. Again using the same we can directly able the treat luminance component upon an image as Y can be directly extracted.

Also if we directly make some modification in RGB colour space it leads to the problems like color distortion and also increase computational complexity. But in case of separation YUV have no such effects upon the colour intensity. Therefore we use YUV rather than RGB directly, but as we have RGB images so we need to convert this into YUV colour space. Relation between RGB colour space and YUV colour space is:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.518 & -0.100 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \ldots\ldots(4)$$

Or we can also use the following formulas for direct conversion:

i) RGB colour space to YUV colour space

Y = 0.299R + 0.587G + 0.114B

U = -0.147R - 0.289G + 0.436B

V = 0.615R - 0.515G - 0.100B

ii) YUV colour space to RGB colour space

$R = Y + 1.140V$

$G = Y - 0.395U - 0.581V$

$B = Y + 2.032U$

3.2.3 Brightness Enhancement using Log-Transformation

It belongs to gray level transformations. This replaces all the input pixel values with its logarithmic values of the image. Log transformation is used for image enhancement. The can be achieve:

$$s=c*Log(1+r) \quad (3)$$

Where, s be the output pixel value of the image, c be the scaling constant and r be the input pixel value of the image.[9]

The log transformation on Y component helps us to brighten the image, as Y component individually can be treated as grayscale image so it is very fruitful to use log-transformation on the image, that indirectly brighten the luminance of the image.

3.2.4 Contrast Enhancement using CLAHE.

Log transformation gives actual information by enhancing the image simultaneously it comes with shortcomings like over enhancement. If the pixel value found as 0 then its log value replace this value with infinite as log(0) is infinite. Such over enhancement leads to loss of information. So why this proposed framework has CLAHE as the next phase to log transformation to control the brightness by contrast management which is a much needed method to this algorithm. In addition to AHE, CLAHE is designed to control the over enhancement of an image. CLAHE directly works upon the tile to treat over enhancement. We can use CLAHE here, which is applied on the luminance channel Y after the log-transformation on same channel, which gives better result in case of YUV colour space as compare to RGB colour space. Again as the CLAHE algorithm mainly focus on local block enhancement or as it is a block based processing it will help in local enhancement of the image which help us to find the each local details from the image easily[10].

3.2.5 Dehazing for removal of Haze Effect.

After the Y component from YUV color space passes through the log-transformation and CLAHE, again the output image get converted back to RGB. Where the converted RGB image may undergoes scattered color pixel values or having haze effects; i.e. haze has two undermining effects on image: it reduces the image contrast and, as well, adds an additive component to the image called air-light which results in a bad or visibly bad image, for removing such effects we proposed Dehazing algorithm.

So that it produce an impactful and eye catching output with all the details of the image. Image dehazing extemporise artistic caharacter, contrast, the character of image real information, which is a very important step for our framework, to provide a proper enhanced output. Also Dehazing provide dynamic colour saturation to the image which results in a better output, that we may observed using histogram equalization.

3.3 Algorithm for Low-Illumination Image Enhancement.

Steps Required:

Begin

Step 1: Select and input a Low-illuminated Image.

Step 2: Convert the RGB color space image into the YUV color space image to get the luminance components.

Step 3: Separate the individual color channel of YUV.

Step 4: Extract the luminance component Y

Step 5: Apply Log transformation on the extracted Y component, i.e. Y_{Log} for brightness enhancement and details retrieval.

Step 6: On the output of log transformation (Y_{Log}), apply contrast limit adaptive histogram equalization (CLAHE) i.e. Y_{CL} to achieve local enhancement and control the over enhancement.

Step 7: Fuse the fuse the contrast limit adaptive histogram equalized output Y_{CL} with the other two chrominance component U and V.

Step 8: Convert the Y_{CL}UV color space to RGB color space i.e. RGB_{out}.

Step 9: Compute the Histogram of RGB output image for estimation of color saturation.

Step 10: Compliment the RGB output image (RGB_{out}).

Step 11: Ap.

ply Dehazing algorithm to the complimented image.

Step 12: Invert the output image.

End

4. EXPERIMENT AND RESULT

4.1 Experiment and results

4.1 dataset

The images are collected from the ExDark dataset. The ExDark dataset is a collection of various types of low-illuminated images:
Low: if illumination is very low and details are visible hardly.

Ambient: This is the type of images with absence of the key light source.

Single: This type refers to a environment with only one single lighting element.

Window: Indoor images with bright windows as light sources.

Twilight: this refers to the image capture at outdoor at the time of very dizzy light effect, i.e. neither very high nor very low light. Time period between dawn and sunrise.

Again proposed low-light image enhancement approach applied on some randomly chosen images because it is very hard to work on every data present in this dataset [11].

4.2. Results

The results are observed by both qualitatively and quantitatively. In the case of enhancement, the visual perception plays an important role but in case of automated systems visual perception is indistinguishable or not a considerable parameter. Hence quantitative measures or analysis are also needed. The qualitative measure mainly deals as a subjective matter while the quantitative measures are deals as a objective manner, both the approach are different in nature with a common aim to illustrate the ratio of enhancement as compare to original image.

4.3. Qualitative analysis

Using human visual perception, this method compared with three techniques i.e. Histogram equalization and CLAHE. From experiment, it can be seen that the images are enhanced better than the three standard methods. Again, it can observe that this method preserves the brightness and details of the images unlike the histogram equalization method, which undergoes over-enhancement. It is also obvious that this method does not enhance the noise to the low-light images to a greater extent like the CLAHE method, which often brings out the noise. .

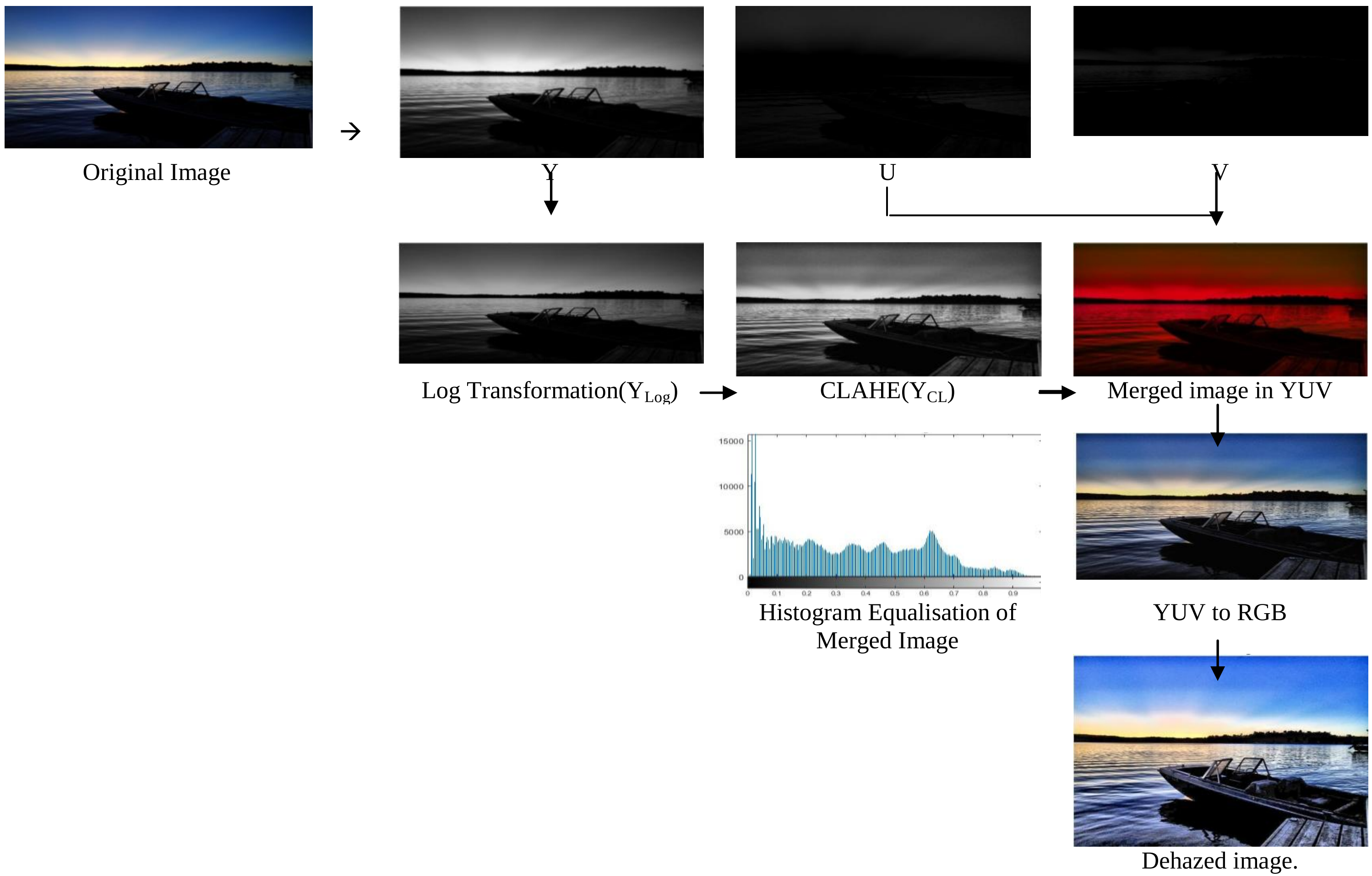
Original Image
Y
U
V
Log Transformation(Y_{Log})
CLAHE(Y_{CL})
Merged image in YUV
15000
10000
5000
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Histogram Equalisation of Merged Image
YUV to RGB
Dehazed image.

Figure No.	Original Image	HE	CLAHE	Log-transform	Proposed Method
1					
2					
3					

4

5

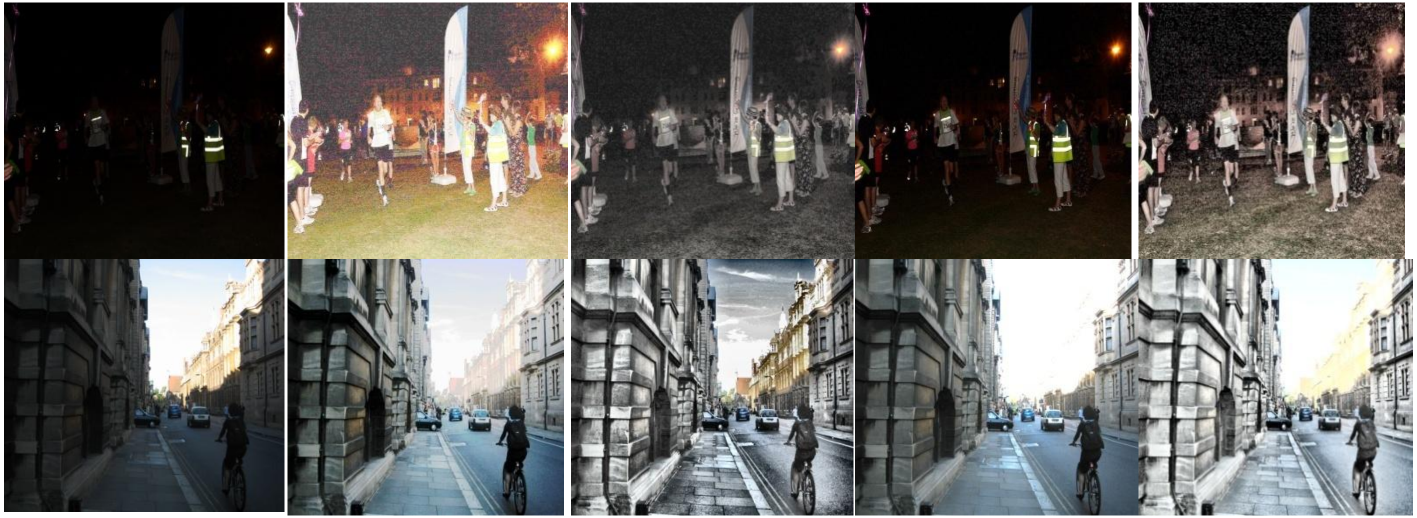

Fig 4.2: (From left to right) Original image, Histogram Equalized Image, CLAHE equalized image, Log-Transformed, Image enhanced in the proposed approach.

Again as we all know that enhancement is a pure subjective term still we proposed the luminance calculation factor so that brightness parameter can be calculated. This factor helps us to check whether the image is enhanced or not.

Table 4.1: Qualitative analysis of figures for Luminance per unit area:

Fig. no.	Original Image	HE	CLAHE	Proposed Method
1	25.3259	135.3321	119.2960	**138.5457**
2	61.4545	129.8674	119.5432	**161.6150**
3	9.7064	**144.0129**	64.7850	77.5008
4	7.0656	**142.7217**	64.4169	80.2585
5	78.0931	131.6686	133.1986	**181.5424**

As the table state the proposed method enhances the image brightness by controlling the over brightness enhancement and this approach also control the over brighten factor to a proper range for an eye catching output.

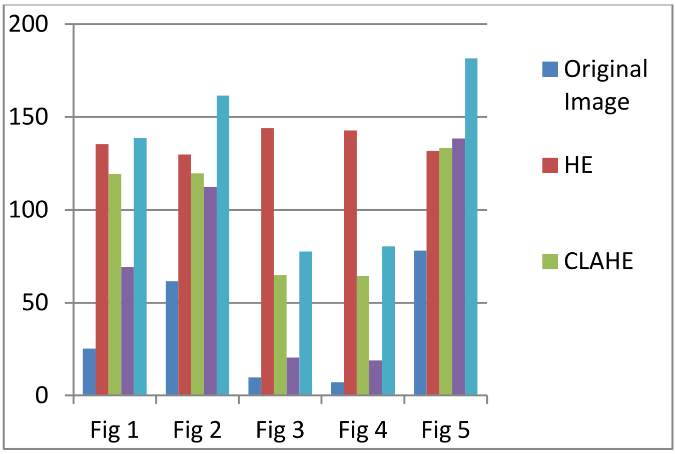

Fig 4.3: Bar Chart for the qualitative analysis.

4.4 QUANTITATIVE ANALYSIS

As we have discussed earlier that qualitative approach is a purely based on human perception, so if we want to apply this into some automated system than this method is of no use; so we also follow the quantitative approached to calculate the objectivity parameter of the image using some statistical measures. A small briefing of the methods:

Mean is the most basic of all statistical measure upon pixels. This accomplished by:

$$\mu = \frac{1}{n}\sum_{1}^{n} x_i \text{ ....()}$$

where x_i represent the pixel values.

1. The standard deviation is a measure of this variability. STD deviation of the image implies a gross measure of the variation about the target value of light intensity, at each data point.

$$\sigma^2 = \frac{1}{n}\sum_{1}^{n} x_i^2 - \mu^2 \text{............()}$$

2. SNR/PSNR

SNR (signal to noise ratio) and PSNR (peak signal to noise ratio) are used to measure the differences between the original image and the enhanced image. The formula for SNR is

$$SNR=\frac{\sum_{i=1}^{M}\sum_{i=1}^{N}|x(i,j)|^2}{\sum_{i=1}^{M}\sum_{i=1}^{N}|y(i,j)|^2} \text{ ....()}$$

Where, *x(i,j)* is the original image and *y(i,j)* be the enhanced image.

$PSNR=10\log_{10}(P^2 / MSE)$ ....()

Where, P is the peak value or maximum value of image data type. Here it is 255.

Table 4.2: Quantitative analysis of figure 1

Parameter	**HE**	**CLAHE**	**Proposed Method**
Mean	127.4404	115.1856	**133.4581**
Std	**75.0326**	64.5309	64.1107
SNR	**12.2330**	13.7412	13.8065
PSNR	6.7084	7.9294	**6.5821**

Table 4.3: Quantitative analysis of figure 2

Parameter	HE	CLAHE	Proposed Method
Mean	127.9547	116.2002	**157.4047**
Std	**74.2598**	61.0609	72.8509
SNR	**12.2598**	14.2939	12.5285
PSNR	9.9489	9.6266	**7.2187**

Table 4.4: Quantitative analysis of figure 3

Parameter	HE	CLAHE	Proposed Method
Mean	**140.3740**	62.8545	76.2081
Std	58.0906	47.0983	**67.0641**
SNR	**10.9705**	16.8903	13.0641
PSNR	**5.2476**	12.3688	9.4663

Table 4.5: Quantitative analysis of figure 4

Parameter	HE	CLAHE	Proposed Method
Mean	**135.3950**	62.3557	77.1933
Std	74.7196	**62.7076**	66.1489
SNR	13.7752	14.0280	**13.4935**
PSNR	9.2354	12.1031	**9.2331**

5. CONCLUSION

This thesis proposes, a new brightness enhancement technique for low-illuminated images based fusion based method. This addresses the problems associated with the low-illuminated images. The proposed method uses the Log-transformation for brightness enhancement, CLAHE for controlling over enhancement and also to achieve local enhancement and Dehazing principle for getting a dynamic output image. Unlike the other methods, it is made specifically for low-illuminated images and works best for them. It also takes care of the problems associated with the local contrast enhancement methods such as enhancement of noise while enhancing the image. The fusion based method makes it easier to avail all objective that are stated above. This method enhances the brightness of the image, prevents over enhancement, preserves details, prevents enhancement of noise, and maintains the local details while brightening the dark areas.

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