A Review Paper on Low Light Image Enhancement Methods for Un-Uniform Illumination

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Abstract- *Image enhancement is the most fundamental steps used to manipulate an image so that the result is more acceptable than the original image, with a try for preserving every detail, in the field of digital image processing. With the high demand of computer visual technology, digital image processing concepts have been rapidly used in many real world applications for information gathering, such as: industrial productions, medical images, video monitoring, intelligent transportations, etc. However, image captured under low light has some issues such that it may contains noise, undergoes color distortion and also may undergoes with some information loss. Again industry like medical and satellite we can't afford single information to be miss, so for that purpose low light image enhancement is a must needed concept for current emerging world. Here in this paper, we analyze different methods of image enhancement and their result, mainly this paper focus on different fusion-based methods, other methods such as retinex based methods, fuzzification etc.*

Keywords: Retinex Model, Fusion Based Method, Pre-Enhancement & Post-Enhancement.

1. INTRODUCTION

In low-light conditions, any images click by the professional or mobile phone camera can be degraded since the sensors receive a lower amount of light. This may result in darken or blacken images in which the observer could not identify the true colours of the objects in these images. In low-light not only the colour but also the objects are not spotted accurately which leads to data or information loss from the image. Again from last several years where digital image processing field is rapidly gain attention and being widely used in industrial production, video monitoring, intelligent transportation, and remote sensing monitoring, traffic sign system, and military applications. But due to low light some unwanted condition may occur such as low illumination, low contrast and high noise. So to conquer the correct form of data or information, we need to enhance those methods.

Image enhancement is one of the most fundamental steps in digital image processing. To remove darkness and extract the exact information from the images are very crucial tasks in applications such as medical imaging, object tracking, face detection, facial attractiveness, and object detection. Therefore, enhancement techniques are much needed technique in this field. For this purpose, different enhancement methods or algorithm have been planned. These algorithms deal with different aspects of image, such as dark areas, noise, light distortion, texture details, colouring, etc. Indeed, the process of eliminating dark areas improves image quality. However, used model to enhance low-light images should not only remove the darkness from images, but also preserve the crucial information of the image. As Images can be degraded as a result of several different conditions, and it is not justify by correcting only one of the factors among them, for which the image quality is get hampered. For example, a technique that is used to improve the brightness or contrast of an image may not be well-suited for images that have high saturated portions. Thus, many important factors need to be checked when applying image enhancement algorithms.

There are various method developed to enhance images. It mainly divided into two parts, Local Enhancement method and Global Enhancement method. The local method enhances the local details of the images; the minute details of the image are focused by the local method which is normally ignored by global method. Local Enhancement methods are based on local characteristics such as computing local statistics like local variance, local mean, etc. Several local contrast enhancement methods are utilized in different images in the different fields, like medical images, real-time images, surveillance applications and many others. Then, several enhancement technique of histogram stretching method over a neighbourhood around the candidate pixel over a sub-region of the image had been introduced and utilized. Sometime the hidden noise of original image comes out which is undesirable. Again Global Enhancement method is very familiar in image enhancement, it mainly deals with the global details of the image that is overall information of the image and ignore the local details of an image. One of the most regularly used methods is Histogram Equalization (HE), where the main motive behind this method is to reassign the intensity value by keeping the histogram stretched and intensity distribution flatter. This methodology works in various places however it lacks to deal with local data.

Again beyond how image get processed, these methods are also get divided into two methods by their domain, i.e. spatial domain methods and frequency domain methods. Spatial domain methods included the modification on histogram and application of spatial filters. Frequency domain methods included the Fourier transforms based image sharpening, image smoothing also we must remember that while using the Fourier transformation it

must undergoes through the inverse Fourier transformation to get a satisfiable output.

In this real world, colour images are most commonly used, so most of the problem solving algorithms are either developed for colour image enhancement or derived from gray image enhancement methods. The most regularly used methods are listed below.

Enhancement based on the RGB (red, green, blue) colour space. The specific steps are: First the individual colours components (R, G and B) are get separated from the original image. Then, these three individual factors are treated with a specific value or method to enhance the original image, with the help of a gray scale image enhancement method. Finally, the three components are collected together, which gives an enhanced image as a output or result.

Enhancement based on the HSI (hue, saturation, intensity).It follows several steps that's are: At first Original RGB image is get converted into the HSI colour space image then, the brightness factor I in the HSI is get separated from image, which is unrelated to the chrominance factor H, which contains the information of an image. As H have image information. Hence, to enhance the image, we have to modify I and S factor which is going to enhance the original image while maintaining the same chromaticity H [1], for details preservation of image than again HIS converted to RGB for required output.

2. RELATED METHODS

Various scholars' works on different Low-Light image enhancement methods. Here are some examples of those methods that are effectively being used such as: Gray transformation method, histogram equalization, frequency domain method, image fusion method. Again these method also has there subparts, according to their work.

2.1 Gray Level Transformation: Gray level transformation operates directly on pixels. The gray level image involves 256 levels of gray and in a histogram, horizontal axis spans from 0 to 255, and the vertical axis depends on the number of pixels in the image. Gray transformation method is a spatial-domain image enhancement algorithm which is working by transforming the gray values of single pixels into other gray values. The simplest formula for image enhancement technique is:

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

Where T is transformation, r is the value of pixels; S is pixel value before and after processing.

Again gray Level Transformation is divided into 3 parts: Linear Transformation and Logarithmic Transformation, Power-Law Transformation.

Linear Transformation: It is again of two types those are identity transformation and negative transformation.

Identity transformation: each value of input image is directly mapped with the output image. i.e.

$$g(x,y)=T\{f(x,y)\} \quad (2)$$

Where T is the transformation that maps a pixel value from f(x,y) into g(x,y), where f(x,y) be the input image and g(x,y) becomes the output image.

Negative Transformation- This is the simplest operation in the digital image processing. Negative is can be formed as:

$$n(x,y)=\{(L-1)-f(x,y)\} \quad (3)$$

Where n(x,y) become the negative transformation and L become the highest pixel value of the image for example 256 for a 8bit image, and the f(x,y) become the input image.

Logarithmic Transformation: It is also of two types: Logarithmic Transformation and Inverse Logarithmic Transformation. The log transformations can be defined by this formula:

$$g(x,y)=c\{\log\{(f(x,y)+1\}. \quad (4)$$

Where g(x,y) and f(x,y) are the pixel values of the output and the input image and c is a constant. The value 1 is added to each of the pixel value of the input image because if there is a pixel intensity of 0 in the image, then log (0) is equal to infinity. So 1 is added, to make the minimum value at least 1.

The log transformation maps a narrow range of low input grey level values into wider range of output values and the inverse log-transfer behave exactly opposite to this.

Power-Law Transformation: The general form of power-law transformation is:

$$g(x,y)=c\{f(x,y)\}\gamma \quad (5)$$

where g(x,y) and f(x,y) are output and input image respectively again c and γ are two positive constant to the equation. Variation in the value of γ varies the enhancement of the images. Different display devices / monitors have their own gamma correction, that's why they display their image at different intensity. This type of transformation is used for enhancing images for different type of display devices.

2.2 Histogram Equalization: Histogram Equalization is used for contrast enhancement. i.e. If the pixel values of an image are uniformly distributed over all the possible gray levels, then the output of this combination result as high contrast image and a large dynamic range. On this basis, the HE algorithm uses the cumulative distribution function (CDF) to adjust the output gray values with the help of a probability density function that leads the gray levels to a uniform distribution; As a result to this method, hidden details can be possible to reappear, and an enhanced output can be expected as a result [2].

Again to counter the drawback of HE method it is developed gradually to BPBHE(Brightness Preserving Bi-Histogram Equalization), DSIHE(Dualistic Sub-Image Histogram Equalisation), MMBEBHE(Minimum Mean Brightness Error Bi-Histogram Equalization), CLAHE, etc.

Brightness Preserving Bi-Histogram Equalization: This histogram equalization(i.e. BBHE) is used to maintain the image brightness, where the input image is get divided into two sub-images(IL and IU)based on the mean brightness of input image, one sub-image is less or equal to the mean and other is greater than to the mean(satisfying the conditional =IL U IU and I =IL∩IU=Ø) using the mean brightness of the original image as a threshold. Than HE is applies to each sub-part for the correction of uneven brightness which gradually leads to local area image enhancement [3].

Dualistic Sub-Image Histogram Equalisation: This similar as BBHE algorithm, it also follow the sub-image principle but it uses cumulative density functions (CDF), and also use the median gray value as a threshold for the division of image into two equal parts to maximize its entropy value, which used for overcoming the loss of information in image caused by the standard HE methods [4].

Minimum Mean Brightness Error Bi-Histogram Equalization: This is used to minimize the mean brightness error between input image and output image. Again this is similar to above two function but instead of using CDF or mean it divide the image such as the brightness between the original image and output image is minimum [5].

Contrast Limited Adaptive Histogram Equalization: The CLAHE uses a Local Contrast Enhancement (LCE). It mainly works on local histogram rather than global histogram. This histogram equalization effectively counters the block effect that arises in other enhancement process and also limits local contrast enhancement by setting a limit parameter, thus it will be able to easily counter the over enhancement of the image contrast [6].

Eventually other Histogram methods are also developed for the purpose of enhance an image i.e RMSHE(Recursive Mean-separate Histogram Equalisation), BPDHE(Brightness Preserving Dynamic Histogram Equalisation), DPHE(Double plateaued Histogram Equalisation), Balanced CLAHE and contrast enhancement, etc.

2.3 Frequency Domain Method: With rapid changes of technology image enhancement techniques also get change from spatial domain to frequency domain. In frequency domain, a digital image is converted from spatial domain to frequency domain [7]. In this method, image filtering is used for a specific application for enhancement purpose. A Fast Fourier transformation is a tool use by frequency domain for conversion of spatial domain into frequency domain. For smoothing an image, low pass filter is implemented and for sharpening an image, high pass filter is implemented. When both the filters are implemented, it is analysed for the ideal filter, Butterworth filter and Gaussian filter. Mainly frequency-domain methods divided as homomorphic Filtering (HF) and wavelet transform (WT) methods.

Homomorphic Filtering(HF): HF-based enhancement methods implement the fundamental principle of the illumination-reflection model to modify the illumination and reflection components in the form of a sum in the logarithmic domain. A high-pass filter is then pass through the image to enhance the high-frequency reflection component again as high pass filter has a nature to pass high frequency and suppress the low-frequency, here also due to high pass filter the illumination component in the Fourier transform domain is get suppressed to provide an proper enhanced output [8].

Wavelet Filtering (WF): As Fourier transformation method, the WT is also a collection mathematical transform functions known as wavelet function which is used for probable evaluation or representation of a signal. The WT not only used to characterize the local features i.e. to alter Local enhancement factors, of signals in the time and frequency domains but also used to conduct a multi-scale analysis of functions or signals through operations such as scaling and translation which leads us to global enhancement as well. In this enhancement algorithm, the input image is, firstly get separated into two different forms that are: - low-frequency and high-frequency image components; then, these image components with different frequencies level are treated individually and result into an enhanced image which able to highlight the details of the image both by locally and globally [9].

2.3 Retinex Methods: This theory, by Land and mcCann, is deals with the perception of colours in view of human eye and the re-modelling of those colour invariance [10]. The objective of this methodology is to determine the reflectance of an image by eliminating the impact of the illumination light from the original image. According to the theory, the human eye acquire information in a specific manner in different lighting circumstances, i.e. when the light strike to the object and reflects, the human eye can detect or sense that object. Again as the above statement clearly describe about the different lighting environment than the main factor on which a human eye can depended is lighting, that is the strength of the light or also may be the unevenness of light. Accordingly, the only factor that reflects essential information or data of any object, such as the reflection coefficient, is retained [11][12]. Based on the above mentioned model, an image can be expressed as follows: that is the product of a reflection component and an illumination component [13]:

$$I(x, y) = R(x, y)L(x, y) \quad (6)$$

Where R(x, y) is the reflection component of the image, L(x, y) is the illumination component of the image, and I (x, y) is the output image.

Single-Scale Retinex: This algorithm comes by a reflected image by estimating the atmospheric brightness. The formula is as follows:

$$\text{Log } R_i(x, j) = \log I_i(x; y) - \log[G(x, y) * I_i(x, y)] \quad (10)$$

Where: I (x; y) is input image, R(x; y) is reflection image, "i" represents the various colour channels, (x;y) represents the pixel positions of image, G(x; y) is Gaussian surround function, and "*"is the convolution operator.

Multi-Scale Retinex: As the SSR have limitation that is to maintain a proper balance between the dynamic range compression and colour consistency, Jobson, Rahman etal. extended the SSR algorithm to a multi-scale algorithm, namely, the MSR algorithm [14], which is expressed as follows:

$$\text{MSR} = \log R_i(x; y)$$

$$= \sum_{n}^{k=1}(\omega_k \{\log I_i(x, y) - \log[G_k(x, y) * I_i]\} \quad) \quad (11)$$

$$\sum_{n}^{k=1}(\omega_k = 1) \quad (12)$$

Where, "i" refer to the three colour channels; "k" refer to Gaussian surround scales; "n" is the individual number of scales and the given parameters are the scale weights. The MSR algorithm has benefits over SSR in term of multiple scales. i.e. the MSR algorithm The MSR algorithm give two main results in enhancement firstly, it enhance the image details and contrast and secondly, this algorithm able to maintain a better colour consistency.

Multi-scale Retinex With Colour Restoration(MSRCR): As SSR or MSR have same methods that is to separate each colour channel and treated them separately, so as comparison to input image, the relative proportions of the treated three colour channels maybe alter after the enhancement of the image, that's why we may face problem like colour distortion or imbalance colour in the output image. To address this, a new method is proposed called as MSRCR. This algorithm specifically have a colour recovery factor C for all individual channels, which is measured proportionally by measuring the relation among the colour channels of the original image and then the proportionate colour recovery factor is used with original image to form a proper enhance image without any colour distortion.

$$C_i(x, y) = f\frac{(I_i(x,y))}{\sum_i^3(I_i(x,y))} \quad (13)$$

Where $C_i(x, y)$ is refer to colour recovery factor, and f become the mapping function.

2.4 Fusion Based Methods: Another direction of research on low-light image enhancement involves methods based on image fusion techniques [14]. In these methods, different images are collected with different sensor or of different scenes, or may be images are collected with same sensor of different scene or vice versa. Finally, as much as useful information from each and every image is extracted and merged into a single frame to synthesize a proper enhanced image which can be used for further operations.

2.5 Fuzzyfication: Fuzzyfication includes fuzzy logic, Membership Functionn, Fuzzy Inference Engine, and De-fuzzyfication. Unlike the standard logic, where the accuracy of the result matters, its all about the relative importance of precision. In other words, it is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, etc.

The primary point of fuzzy logic is to map an input space to output space. It is generally done by different set of rules. Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is differ from crisp set, clearly defined boundary. It can contain elements with only a partial degree of membership. Similarly in fuzzy logic, the degrees of membership functions are evaluated to draw any conclusion.

3. LITERATURE REVIEW:

Ratinex based methods and fusion based methods are widely used methods for the colour image enhancement from last several years. There has several methods over colour image enhancement, that is; Ziaur Rahman et al[15]. produce an fusion based enhancement method by using the CRM and De-hazing concept, it is an efficient naturalness preserved method to enhance low-light images however it mainly depends on different exposure map estimation strategies, also this method is only used for a particular camera response model and not tested for other models as well, still it provide a proper enhancement techniques and gives the desire output, with some short comings such as it over enhanced the extremely bright portion of original image. Ghada Sandoub et al[16]. It proposed fusion based low light image enhancement algorithm consisting of two main steps firstly the fusion-based bright channel estimation and secondly the refinement. The bright channel representing the insufficient illumination of the input image is estimated by fusing both the bright channel prior and the maximum colour channel. Again it followed by another refinement algorithm to improve the sharpness of the initially enhanced image, so why it is able to perform the global enhancement of the image, but it lack in local contrast enhancement. Zhenqiang Ying et al.[17]proposed framework combining the camera response model and traditional Retinex model. As per their framework, it proposes an accurate camera response model that able can reduce the mean RMSE by an order of magnitude and also present a fast solution to the exposure map estimation. Sasi Gopalan et al[18]. Here it uses fuzzy concepts. Its equations and functions are considered in the fuzzy domain. Triangular membership function, sigmoid operators are used to move from real world into the abstract world of mathematical concepts. Again Scaling of a output membership function helped to avoid discontinuity in the histogram of the image. Though it is able to enhanced the images still it seems that it is goes through the over enhancement. Minseo Kim, etal[19].This method used the concept of PCA(Principal Component Analysis), this method simplifies the atmospheric light estimation using the feature of haze patches analysed by the principal component analysis so that it can able to fuse two method of PCA and hazing concept to get an enhanced image. Because of which this method is able to get a proper

enhanced image even in low light. Steffi Agino Priyanka et al[20].propose an effective CED algorithm that perform contrast enhancement and de-noising for night images. Retinex based adaptive filter is applied in three scales to improve the contrast and brightness significantly again here PCA is used which is used to explores the variance-covariance or correlation structure of samples in vector form. It uncovers the spectral properties of colorants to process the information for better results. Again though it provides and appropriate enhancement result still it undergoes with some chances of information loss. ZhenfeiGuet al. proposed a simple but physically valid low-light image degradation model (LIDM) which is derived from the atmospheric scattering model. Te proposed model inherits the main physical meaning of ASM, shares the basic concept of the "inverted low-light image enhancement model," and overcomes their inherent limitations [21], which provides a refined method for enhancement. Sarath K et al.[22] it is a fusion based method which use new concept that has been developed for the purpose of enhancing images based on fuzzy logic with homomorphic filtering technique, which resulting in enhanced high contrast image. It is successfully implemented however it seems for some images that it over enhance a particular part of the image.

Table 3.1: Summery table of Low Light Image Enhancement Method.

Sl. No.	Author	Topic	Method	Findings
1	ZiaurRahmanet. al.	A Smart System for Low-Light Image Enhancement with Color Constancy and Detail Manipulation in Complex Light Environments	Fusion-based method	It enhances the result but When it comes to images with extremely bright and dark portions, the enhancement algorithm over-enhanced the bright portion.
2	GhadaSandoubet. al.	A low-light image enhancement method based on bright channel prior and maximum color channel	fusion-based low-light image enhancement algorithm	the global contrast of the image can be improved
3	Zhenqiang Ying et al.	A New Low-Light Image Enhancement Algorithm using Camera Response Model	Fusion Based algorithm	It enhances the result however this method works for specific or fixed camera parameters. Also it is unable to understand different features of image and can't configure very details of the image scene content, so some time over enhancement is occurs.
4	SasiGopalan et al.	A New Mathematical Model in Image Enhancement Problem	fuzzification	Very useful for enhancement but some time it provide over enhancement.
5	MinseoKimet al.	Image Dehazing and Enhancement Using Principal Component Analysis and Modified Haze Features	PCA and Computational Haze removal methods	provide high-quality images for various image Processing applications in haze and low-light condition.
6	Steffi AginoPriyanka et al.	Low-Light Image Enhancement by Principal Component Analysis	PCA with multi-retinex based adaptive filter.	It Provide a effective enhance image even in more darker image as in night time image. However some information may get loss in this method.
7	ZhenfeiGuet. al.	A Low-Light Image Enhancement Method Based on Image Degradation Model	Low-light image degradation model derived from the atmospheric	It provides a refined way for image Enhancement.

		and Pure Pixel Ratio Prior	scattering model,	
8	Sarath K et. al.	Image Enhancement Using Fuzzy Logic	fuzzy logic and hioomophic filtering based method	This Method enhances the images however this is undergoes through the over enhancement .sometimes.

4. CONCLUSION:

After reviewing different papers and different method, it can be cleared that there has mainly two broad categories for low light image enhancement techniques that is Pre-Enhancement and Post-Enhancement. Pre-enhancement is the methods where we impose our enhancement methodology before capturing any picture and the Post-enhancement is the culture of techniques which are used after the image is captured. There are various method belongs to these two categories with a purpose to enhance a low light image. It has been observed that each method has its own advantages and shortcomings. That is some methods undergoes over-enhanced, some methods have higher complexity and some methods are also impressive with their result but these are financially expensive when it comes to computation and also for capturing any image for dataset. So we can conclude that instead using a single method with all its shortcomings, if we can able to merge two or more methods and create a fusion based method so that one method became the advantages for other method shortcoming and able to provide a proper output that it can be helpful in low light image enhancement and also help to sustained the main purpose of low-light image enhancement by extracting all hidden details from the image due to low light.

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