

A Review on Image Enhancement Techniques using Histogram Equalization

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Abstract— Image Enhancement (IE) is vital and one of the significant parts of Image processing. It is necessary to enhance the contrast and reduce the noise to improve the quality of the image. IE is one of the processes for altering the visibility of an image. It is widely applied in different fields such as medical science, industry, military, agriculture, etc. Image Enhancement is modifying digital images to make the image appear pleasing to the viewer. Several research works have been done on Image Enhancement. This paper also discusses the Self-Calibrated Illumination method (SCIM) and the HE method. SCIM along with HE Image Enhancement techniques and algorithms can improve the visual quality of the digital image. There are several techniques to enhance the quality of an image to extract meaningful information from the image. The well-known techniques for image enhancement are the RetiNex-based method, Weber-Fechner method, Linear Regression algorithm-based method, Histogram Equalization, Fourier transform, etc. This paper reviews and compares the research work carried out in image enhancement based on the Histogram Equalization Method by different authors. This paper also reviews the merits and drawbacks along with the enhanced images and histogram plots obtained in these methods developed over the past decades. Finally, it concludes what further work needs to be done for a better quality of image.

Index Terms— Histogram Equalization, Weber-Fechner, Self-Calibrated Illumination, Linear Regression

I. INTRODUCTION

Image Enhancement is used to improve the visibility and perception of information in images. It also provides a good solution as input to other automated digital image processing techniques. The main goal of IE is to modify a digital image's attributes and produce an image more suitable for a given task. Histogram Equalization [1] has been used to enhance the quality of the image. It is used to improve the contrast of an image by redistributing the pixel intensity in the image so that the pixel values are more uniformly distributed. This makes the image more visually appealing. Along with this method, another method called the Self-Calibrated Illumination method [2] is used to improve the quality of the image. Most digital images sequenced from gathering equipment are too bright or dark and have an unbalanced background as a result of environmental factors, especially illumination as in [3]. As a result, the images lose some detailed information and quality, which has a significant impact on how they are used for things like transportation, public security, punishment detection, and other purposes. The histogram plot of different methods shows the distribution of pixel intensity of the image. Histogram Equalization (HE) along with Self-Calibrated Illumination is a preferred choice for images with low contrast and with less noise. It is one

of the most acceptable Image Enhancement algorithms. The proposed technique based on Histogram Equalization along with Self-Calibrated Illumination method shows improved performance to the existing image enhancement approaches. HE accumulates the histogram probability density of the function of an image so that the grayscale distribution of an image can be enlarged. Various algorithms for accomplishing the contrast of an image have been developed and applied to the problems of image processing.

The proposed Self-calibrated Illumination method (SCIM) uses a reference image to calculate the illumination condition of the image. This information is then used to improve the contrast and visibility of details in the output image. The SCIM along with the HE method has several merits as it improves the contrast of the image, it helps to reduce noise, it also helps in edge detection of an image by making the edge sharper. The combination of the two techniques helps to reduce the artifacts and is used in a wide area such as medical imaging, in security applications.

II. LITERATURE REVIEW

Various research works done in the field of Image Enhancement Techniques using Histogram Equalization are summarized in Table I. A comparison of the Enhanced Images obtained by some of the methods with their histogram plot and the drawbacks of these methods is depicted in Table II.

III. PROPOSED METHOD

The result of the output images obtained from the various methods has some drawbacks such as over-enhancement, the lack to preserve the brightness, the presence of noise, etc. Our proposed method which is based on Self-Calibrated Illumination and Histogram Equalization technique has somehow been able to overcome these drawbacks. The proposed method can yield pleasing results with the preservation of brightness and structures and even improve the visual quality of the image. We create a unique Self-Calibrated Illumination (SCI) learning framework for quick, adaptable, and reliable low-light image improvement to address the problems. We create a self-calibrated illumination learning module to ensure convergence between findings at each stage, enhance exposure stability, and significantly lessen the computational load. The flowchart for the self-calibrated illumination method is depicted here:

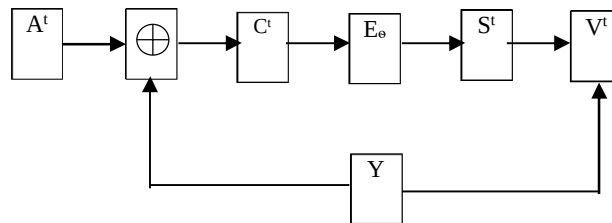


Figure 1. Flowchart for the self-calibrated illumination method

The original low-light input is combined with the self-calibrated module map as the input of the illumination estimation in the following stage.

The following equations can be obtained from the above framework:

$$G(A^t) : C^t = Y \oplus A^t \quad \text{-----(1)}$$

$$S^t = E_\theta(C^t) \quad \text{-----(2)}$$

$$V^t = Y + S^t \quad \text{-----(3)}$$

Where Y is the low light dark image; A^t is the illumination component at t^{th} stage.

The Equations obtained from the SCI framework have been defined as follows:

The first equation (1) states that the transformation $G(A^t)$ adds the estimated illumination Y to the image pixel values A^t . A new image C^t that has been brightened by the estimated illumination's quantity is the end result of this operation.

The second equation (2) states that the transformation $S^t = E_\theta(C^t)$ transforms the image C^t according to a nonlinear function θ . The function θ is a gamma correction function, which shrinks the image's dark pixels and enlarges its bright pixels. The end effect of this alteration is a new image S^t with improved contrast.

The third equation (3) states that the improved image S^t is added back to the estimated illumination Y by the transformation $V^t = Y + S^t$. The outcome of this transformation is the final enhanced image V^t .

Every process step that is shared aims to achieve a result that is as close to the desired outcome as possible. The input of each stage is derived from the input of the stage before it, and the input of the first stage is definitely the observation in low light.

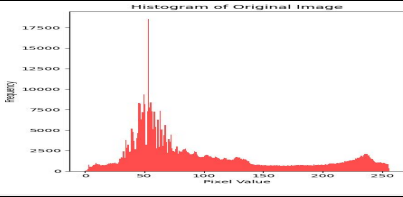
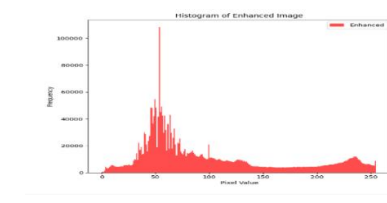
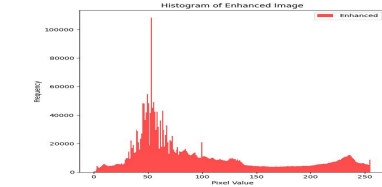
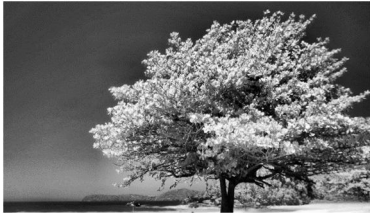
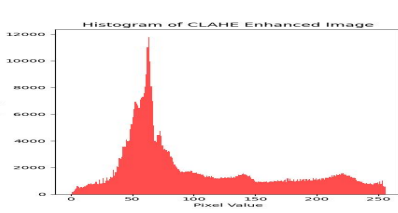
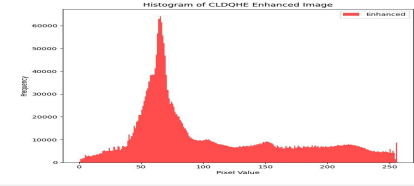
The flowchart in Fig. 2 showing the working of Self -Calibrated Illumination method along with the Histogram Equalization method is depicted below:

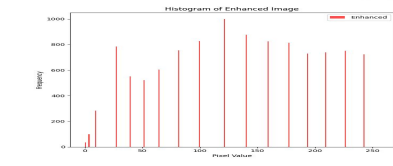
TABLE I. VARIOUS WORK DONE IN THE FIELD OF IMAGE ENHANCEMENT TECHNIQUES

Ser. no.	Author Name	Paper Name	Advantages	Drawbacks
1	Y. Xie,L Ning, M Wang et.al.(2019) [1]	Enhancement of image using histogram equalization	The visual effect and contrast can both be enhanced by histogram equalization	It may cause judder and loudness.
2	Z Huang,Z Wang et al. (2021) [2]	Image Enhancement with the preservation of brightness and structures by employing contrast-limited dynamic quadri-histogram equalization	With the preservation of brightness and structures, the CLDQHE process can produce pleasant results.	The method fails to produce the details and high contrast of the image.
3	J Xiong, D Yu , et al. (2021)[3]	Application of Histogram Equalization for Image Enhancement in Corrosion Areas	The suggested technique considerably raises overall brightness, intensifies shadow detail, and strengthens corrosion area identification in the image.	The proposed method combine two algorithm this leads the computational complexity very high.
4	S Chaudhary et.al. (2022) [4]	Enhancement of images by linear Regression algorithm and sub-histogram equalization	The algorithm is applied on both medical and nonmedical images which improve its performance.	The method requires the set of various test images to evaluate its performance which is sometimes is cumbersome.
5	U.K. Acharya et.al (2022)[5]	Sub-division of image and quadruple clipped adaptive histogram equalization for low exposure image enhancement	The method used can enhance the contrast of low-light images	The method may not be suitable for images that contain more noise
6	N Thakur et.al. (2022)[6][9][7]	Cuckoo Search Optimized Histogram Equalization for low contrast image enhancement	This method control over and under enhancement by calculating clip limits of the image histogram.	This approach has the potential to reduce the quality of the resulting low contrast images. ,
7	Y Li, Z Yuan, K Zheng et al.(2022)[8]	A weighted histogram equalization method for brightness preserving image enhancement based on partial statistic and global mapping model	This technique may efficiently enhance image details, reduce over-enhancement, and increase visual quality while maintaining image brightness.	The histogram's high peak causes over-enhancement, which significantly degrades the subjective quality of the HE-processed image.
8	S.D. Thepade et.al. (2022) [9]	Contrast enhancement with brightness preservation of low light images using a blending of CLAHE and BPDHE histogram equalization methods	This approach is straightforward and very efficient,	There is a need for improvement because this method sometimes is unable to maintain the brightness and natural form of the original scene.
9	Y Jin, W Yang et.al.(2022)[11]	Unsupervised Night Image Enhancement: When Layer Decomposition Meets Light-Effects Suppression.	This method boost the intensity of dark regions and reduce hallucinations and other artifacts.	This method leads to over enhancement and saturation in bright regions.
10	W. Wang et.al. (August 2022)[19][10]	Simple low-light image enhancement based on Weber-Fechner law in logarithmic space	The method reduces the impact of non-uniform illumination on the image.	There is a lack of parameter setups to change on their own during the process of improving low-light photos

11	F.M. Mustafa (2022)[12]	Enhancement of image in wavelet domain based on histogram equalization and median filter	The proposed method help in reducing the noise from the mage.	This algorithm lacks in selecting suitable filters to produce improved quality and performance results.
12	S Agrawal , R Panda et.al.(April, 2022)[14]	A novel joint histogram equalization-based image contrast enhancement	Even for images with a limited dynamic range, it gives the best results.	The use of joint histogram may make it more complex contrast enhancement techniques.
13	Long Ma, Tengyu Ma et al.(2022)[16]	Toward Fast, Flexible, and Robust Low-Light Image Enhancement	This method is fast enough to use in real-time applications.	This method requires a large amount of data for training which is the main demerit.

TABLE II. COMPARISON OF THE ENHANCED IMAGES OBTAINED BY THE FOLLOWING METHODS WITH THEIR HISTOGRAM PLOT AND THE DRAWBACKS OF THESE METHODS

Methods Name	Enhanced Images obtained from the respective methods	Histogram of the enhanced images of the respective methods	Drawbacks of these respective methods
Original Image(input images)[32]			This input grayscale image is dull, dark, and has low contrast. The histogram plot is denser near 0 to 150 which results in dark contrast of the image
Brightness preserving Bi HE methods (BBHE)			The subjective quality of the image processed by HE is significantly impacted by the over-enhancement brought on by a high peak in the histogram.
Linear Regression algorithm and Sub HE technique.			The result as displayed is in terms of different evaluation measures. The pixel intensity value in the histogram shows a high peak near 50 and 100, resulting in a Dark appearance of the output image.
Blending CLAHE and brightness-preserving dynamic HE methods (BPDHE)			The displayed output needs to improve the brightness as the pixel's intensity value in the histogram plot is denser near 50 to 100. So, it did not keep the original scene's brightness.
Contrast Limited Dynamic Quadri-HE method (CLDQHE)			The method retains the structure in the output image but it fails to preserve the brightness. The pixel intensity of the histogram plot is denser at 75 which is nearer to the dark region i.e. close to 0.

HE based on the Cuckoo search algorithm			This method reduces the final image's quality by adding washed-out forms due to excessive brightness change.
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- 1) Read the dark low light image from a file or from outward tool such as a camera.
- 2) Apply Histogram Equalization to the image. HE results in an image with bright contrast and improved visibility.
- 3) Calculate the illumination of the image using Self Calibrated Illumination Method equation.
- 4) Apply the scaled illumination to the HE enhanced image, this results in a more accurate visibility.
- 5) The final step is to save the enhanced image to display it on a screen.

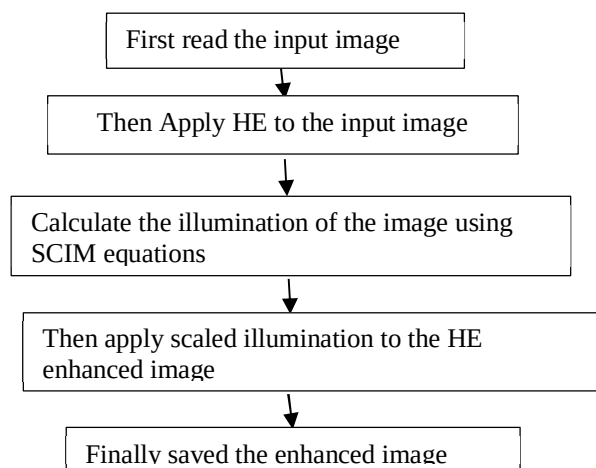


Figure 2. Flowchart for the self-calibrated illumination method

IV. DISCUSSION

Histogram Equalization is one of the image processing techniques that helps to adjust the contrast of the image with the help of its histogram. In order to enhance the contrast of the image the Histogram Equalization stretches out the intensity range of the image. By doing this the Histogram Equalization enables the low-contrast image to gain high contrast. We need Histogram Equalization when the image looks washed out as these images do not have sufficient contrast. In order to get high contrast in the image Self-Calibrated Illumination method is also applied to the equalized image which we get from the Histogram Equalization Method. Most of the pictures that are used in computer vision and image processing task does not provide much information since most of the areas of the images are blurry due to a lack of contrast. So Histogram Equalization along with the Self-Calibrated Illumination Method is used to get the bright contrast of the input image. The SCIM (Self-Calibrated Illumination method) along with the Histogram Equalization method used in this paper is far better than all the state-of-the-art methods.

V. CONCLUSION

The Histogram Equalization along with the Self-Calibrated Illumination method is used in this paper not only to improve the quality of the grayscale images but also to remove all sorts of artifacts such as noise from images. The drawbacks which were seen like some blurring artifacts in the grayscale images are also removed by this Histogram Equalization and Self-Calibrated Illumination method. We create a new self-calibrated Illumination (SCI) learning framework in this research for quick adaptable and reliable image brightening in actual low-light conditions. Finally, further exploration is needed in designing more effective image enhancement techniques that can provide a bright contrast image. So, more research work needs to be done in the image enhancement area.

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