An Enhanced Adaptive Histogram Equalization Based Local Contrast Preserving Technique for HDR Images

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Abstract. To improve the visualization of an image, the image enhancement techniques enhance the assured features of an image. In this work, the algorithm will enhance medical as well as normal or natural images which are captured in low light and day light conditions. An enhanced adaptive histogram equalization based local contrast preserving technique is developed with the help of image processing methods such as changing colour spaces, inverting images, dehazing, increasing saturation etc. The algorithm proposed here is intended to maintain the local image details while attaining the contrast enhancement. To express the performance of this algorithm, the image quality metrics calculated are peak signal to noise ratio and normalized absolute error. This metric parameters show that this model has better performance when compared to other existing methods.

Keywords: Local Contrast Preserving Technique, Characteristics of Image, Histogram Equalization, Image Enhancement, Image Processing.

1. Introduction

Image enhancement techniques are usually preferred for enhancing the medical as well as natural image quality. Improved image offers advanced information on behalf of human spectators and assist additional study of image. Image Enhancement techniques can be categorized as transform domain method and spatial domain method. Improved image is obtained by spatial domain method by just influencing the intensity value of respective pixels in an image. Different transform techniques like Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT) helps in improving the image intensity in transform domain. In further terms, in transform methods, an image is improved through varying its frequency content like edge and further delicate data [1].

Histogram equalization (HE) is an easy as well as famous technique for improving the contrast of an image that offers a common summary of an improved image and helpful in various image processing applications [2, 3]. Histogram Equalization helps in improving the image contrast as a result, it possesses an outcome of extending the Dynamic Range of an image. HE shows elevated concert in improving the contrast of a specified image. Nonetheless, it differ the brightness of an original input image, poor visual quality, and introduce certain unwanted noise.

Global histogram equalization (GHE) and local histogram equalization (LHE) are very much helpful in determining the problems that arises while applying the traditional histogram equalization (THE).
GHE is apt for image usual enhancement; still, this technique fails for reserving the brightness feature of the input image. LHE is very much helpful to tackle issues that arise while applying GHE. LHE utilizes a method called sliding window which moves over every pixel of the image. Pixels that exist in the window are favored for histogram equalization, and on the middle pixel of the window the gray level mapping is done. On the other hand the computational cost for LHE method is very high and also there is probability of over-enhancement in some portions of image.

**Our Contribution:**
- To enhance the histogram adjustment technique for HDR images.
- To develop an algorithm to improve the quality of service QoS for visualization of high dynamic range imaging.

The study is prearranged as; second part gives a literature survey. Third part illustrates research methodology and fourth section depicted proposed algorithm. Section 5 provides the results and discussion and comparison of results with existing methods and concluded the paper in section 6.

2. Literature Review

Parihar et al, (2020) offered a complete study of image enhancement methods on the basis of multi-fusion. It gave an approaching into the procedure utilized in every technique, together with its execution structure. Lastly, a comparison was made amid a variety of methods based on different parameters [4].

Jia et al, (2020) proposed a well-organized in addition to adaptive tone mapping procedure on the basis of guided image filter (GIF). High dynamic range image was compacted adaptive as per its average luminance. After that they decomposed it into a base as well as a detail layers by means of a GIF. Base layer was improved moreover enhanced detail layer at the same time, and combined two layers to obtain a final LDR image. As the parameters was connected by means of image statistics, they adaptively apt for different images. Evaluation of objective outcomes on sets of HDR image demonstrated an advantage of the suggested method. For the moment, the outcome of the procedure could decrease the halo artifacts as well as preserved additional feature through subjective study [5].

Lv et al, (2019) proposed a novel infrared based algorithm for image enhancement to improve the image contrast on the basis of CLAHE as well as multi-scale procedure of DoG. Initially, guided image filter GIF was used to divide base as well as detail layer of an image. After that, an enhanced CLAHE was preferred to change the global contrast of base layer. To improve the detail features and to remove the noise from the detailed layer a multi scale fast median filter is used. Lastly, two layers were combined as per the weight of noise level of detail layers’. Contrasting with real-time techniques in qualitative as well as quantitative aspect, the suggested technique showed the improved concert in experimentation outcomes [6].

Raikwar et al, (2020) presented a quick and precise technique for single image dehazing. This technique functioned in two parts viz., an adaptive dehazing control factor for approximate exact transmission, and a mathematical model which shows the probability of a pixel to be at small distance is proposed to compute atmospheric light in locating haziest region. This technique obtained visually convincing outcomes, and recovered the information content precisely. Computation speed as well as accuracy of the suggested technique was verified by means of quantitative as well as qualitative assessment of outcomes with advanced dehazing techniques [7].

Mayathevar et al, (2020) constructed a method called fuzzy dissimilarity histogram. The neighborhood features of an image to enhance the intensity, contrast as well as spontaneity of an image. After that,
gamma correction is included for additional improvement in dark areas. Lastly, to avoid the fading effect the saturation is modified to permissible limit. Investigational outcomes on various scenes demonstrated that suggested method enhanced the quality as well as particulars of an image competently. Objective measures showed competitive concert of projected method than the further techniques [8].

Zhou et al, (2019) proposed an enhanced adaptive detail procedure for infrared images on the basis of a guided image filter. Threshold for base layer image is adaptively selected as per the histogram statistical data and adjusted mapping range of histograms as per image dynamic range (DR). In addition, detail layer is hold by a simple adaptive gain control technique to attain the good detail enhancement effect. Lastly, base layer as well as detail were combined as per the estimated fraction of the background and the particulars. Investigational outcomes showed that this procedure adaptively and effectively enhanced various DR images in various situations. Furthermore, this procedure has high real-time concert [9].

Shi et al, (2019) proposed a procedure on the basis of HE that possesses saturation preservation and attained more appropriate visual perception. This technique solved the issue of visual perception saturation reduce and color distortion produced through traditional histogram techniques. The outcomes showed outstanding concert in enhancement of LDR image [10].

Yang et al, (2019) presented a well-organized technique for removal of haze and correction of overexposure and presented a technique for image fusion. An OE image is modeled as common image exposure added with asymmetrical colorful haze layer, and the data submerged in OE is improved by enhanced haze removal method prior to dark channel. The outcome possessed an improvement and enhanced visualization of image in OE areas and color distortion to an assured level. The image fusion method based on weighted least squares filters and global contrast-based saliency; the texture attained in OE areas was used to re-establish the overexposure. Benefits of the preferred image fusion method were authenticating in the study. In the experimentation, the projected technique was evaluated through usual techniques to confirm the concert. The subjective visualization in addition to quantitative indicators showed that the outcome was efficient in correcting the overexposure without raising false information and over saturation [11].

Dar, Khursheed Ahmad et al, (2020) proposed a new multi scale Retinex (MSR) tone reproduction based algorithm for HDR Images. Instead of Gaussian filter weighted edge preserving filter is used to avoid the halo artifacts during contrast enhancement of an image. This technique provides the useful information of converted HDR images after histogram equalization and has good features to use the images in LDR devices [13].

3. Research Methodology

The method presented here is an integration of two methods: CLAHE in addition to local image contrast preserving dynamic range compression. Ranges of local image contrast enhancement factor differ from one image to other image. This technique restricts intensification and conserves local particulars of an image. In this technique, probability of under as well as over enhancement gets decreased and range of gain parameter also changes linearly over edge density of image. The experiment is done on both medical as well as natural images. The below subsections present a concise explanation of CLAHE as well as local contrast preserving Dynamic Range compression correspondingly.

An adaptive histogram equalization (AHE) technique is utilized to develop contrast in images. This technique differs from simple Histogram Equalization method in respect that an adaptive histogram
technique calculates various histograms, every equivalent to a different image section, and utilizes them to reallocate image lightness values. It is then apt for enhancing the local contrast and improving edge definitions in every area of an image. The CLAHE method prevents restricting amplification that caused by over amplification of AHE in fairly identical regions of an image. Ordinary HE utilizes the similar transformation resulting from the image histogram to change all image pixels. This functions well once pixel values distribution is alike all over the image. But, once the image has areas that are considerably lighter or darker than most of an image, contrast in those areas will not be adequately improved.

![Block Diagram of Existing Method](image)

**Figure 1.** Block Diagram of Existing Method

Adaptive histogram equalization enhances every pixel of an image with a transformation function resulting from a neighborhood area. This technique was initially used in aircraft cockpit displays. Every pixel is changed dependent on the histogram of a square encompassing the pixel, The induction of the change capacities from the histograms is actually equivalent to for standard histogram adjustment: The derivation of transformation functions from histograms is precisely similar as for ordinary HE: Transformation function is comparative to Cumulative Distribution Function (CDF) of pixel values in neighborhood. Pixels near image boundary need to be treat specifically, as their neighborhood may not be positioned totally in an image. This apply for instance to pixels to left or beyond the blue pixel in figure. This can be solving by enlarging the image by reflecting pixel lines and columns with regard to an image boundary. Just copying the pixel lines on the edge is not suitable, as it would lead to an extremely peaked neighborhood histogram.

CLAHE is an enhanced technique of AHE. The image is divided into tiles by CLAHE method i.e., contextual regions. The histogram is made of every contextual area and at predefined value clipping is done. The redistribution of clipped quantity is done among histogram bins. CLAHE is a customized form of actual histogram and resolves an edge shadowing outcome of AHE and the issue of over enhancement is decreased. The CLAHE technique makes image feature noticeable by redistributing the utilized gray values. The method has verified its achievements for the improvement of low contrast medical images.

The 2D convolution Gaussian smoothing operator is utilized to blur the images and eliminate the noise from the image. It is analogous to mean filter and it utilizes a different kernel that specifies Gaussian ('bell-shaped') hump shape. This kernel has certain individual properties that are described below. The Gaussian distribution in 1-D has the structure:

\[
G(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}
\]

Where
\( \sigma \) is a standard deviation of Gaussian distribution
We have to understood that the distribution has a mean of zero.

There are a number of techniques for enhancement of image. Certain techniques possesses drawback of improving the noise of background. Many techniques undergo from the ordinary issue of over as well as under-enhancement that can’t safeguard local image particulars intended for additional study. Number of techniques was suggested by few researchers with global gain parameters for contrast enhancement. Global gain parameters cannot conserve the local contrast of the image. These problems take place owing to the actuality that these techniques do not reflect on the local intensity for contrast improvement. In this work, the fundamental idea of preserving the local contrast of dynamic range compression is projected. This technique utilizes local gain parameter. The Gain parameters depend on an image pixel neighborhood edge density. The difficulty of over and under enhancement is decreased with local gain parameters. The block diagram of the proposed technique is shown below in Figure 2. Various subjective as well as objective estimation criterions were utilized to judge against the concert of the suggested technique by means of CLAHE. The proposed procedure is useful to huge quantity of medical as well as natural images.

**Disadvantages:**
- Low PSNR value
- Low MSR value
- High NAE Value
- Visual appearance is not good due to over enhancement

4. **Proposed Methodology**

The block diagram of our proposed technique is revealed under:

![Proposed Methodology Diagram](image)

**Figure 2.** Proposed method block diagram

RGB color mode type, obtains a variety of colors through the alteration of three color channels Red (R), Green (G), Blue (B) and the superposition principle among them, RGB represents the red, green, and blue channels. RGB color model on the basis of the Cartesian coordinate scheme, every color appears in red, green, and blue primaries spectral units, model is very satisfactory to the hardware’s implementation, and matches the fact that human eye is sensitive to red, green, and blue, but do not reflect the essential differences among the colors, cannot be consistent with human’s perception of color. In order to easily describe the color image conducting color description, so as to in line with human’s feeling facts of color.
Apart from color space, it’s significant to recognize what L*, a*, and b* stand for.

- **L***: Lightness
- **a***: Red/Green Value
- **b***: Blue/Yellow Value
- **a***: axis run from left to right. A color measurement movement in +a direction portray a move in the direction of red.
- **b***: axis, +b movement signify a move in the direction of yellow.
- **Center L*** axis show L = 0 at base.
- **At plane center is neutral.**

Colour inversion, also recognized as a negative effect, is one of the easiest effects to attain in image processing. Colour inversion is attained by subtracting every RGB colour value from the utmost probable value (usually 255). Another effect which is linked to colour inversion is solarize effect. The variation amid the solarize effect and colour inversion is that by means of the solarize effect only colour values beyond or beneath a set threshold are reversed.

Outdoor images be unable to find their worth due to mirror image of sunbeams i.e. haze or fog or smog. Haze is an ordinary procedure that dust as well as smoke particle replicates sunlight casing visualization loss. Visibility from camera is discolored owing to the intrusion with the ecological light source reflect by dust particles. Blurred images increase noise and lose the colour attenuation. Haze removal is extremely wanted in various areas similar to computer vision, image processing and photography. Initially, elimination of haze from an image raises hazy image visibility produced by atmospheric particles. In the majority of computer image processing methods, as of bigger scale image processing to highly developed scale shape detection prefers that the resultant image is a scene Luminant. Assessment of such methods is depended on scenes. If view is dull, then vision procedures faces a lot of concerns and do not give efficient concert. Consequently, elimination of haze is desired for enhanced outcomes and efficiency. The bad images can be place to better usage. Quantity of dispersal depends on length of the scene from camera and deprivation is spatial-variant. Elimination of mist from an image raises hazy image visibility produced by atmospheric particles.

In the digital image acquisition, processing (such as image compression), the transmission and recording of the process, due to imperfect imaging scheme, processing process, transmission medium and recording apparatus, integrated by means of the movement of objects, defocus reasons, inevitably brought some image color distortions. Distortion is an adjustment of an original shape of somewhat. In communications in addition to electronics it refer the adjustment of waveform of an information-bearing signal, like an audio signal showing sound or a video signal showing image, in an electronic device.

Distortion is typically unnecessary, moreover so engineers struggle toward remove or else lessen it. In certain circumstances still distortion could be wanted. Such as, in broadcast of FM along with noise reduction schemes such as Dolby scheme, an audio signal is intentionally hazy in way which highlights signal aspects that are matter to electrical noise, after that it is symmetrically "undistorted" subsequent to passing over a noisy communiqué channel, decreasing noise in signal. Distortion is also preferred as a musical impact, mainly by means of electric guitars.

In photography, we have two types of distortions, the optical and perspective. Both lead in certain type deformation in images – a few frivolously and others very visibly. Optical distortion (often called lens distortion) is due to an optical design of lenses and perspective distortion is caused by the position of camera comparative to a subject or by a position of subject in the image frame. And it is definitely
significant to differentiate among these distortions types and recognize them, as you will observe them all fairly a bit in photography.

Image noise is arbitrary difference of brightness in the images captured. It is deprivation in image signal produced through outer sources. Images with multiplicative noise possesses the feature that brighter the region the noisier it. But frequently it is additive. We can form a noisy image as:

\[ A(x,y) = H(x,y) + B(x,y) \quad (2) \]

Where, \( A(x,y) \) is the noisy image function, \( H(x,y) \) is the image noise function, and \( B(x,y) \) is the original image function.

One basic challenge in image processing field as well as computer vision is image denoising. Image noise might be due to various intrinsic and extrinsic situations. Consequently, image denoising shows a vital part in an extensive range of applications like image restoration, visual tracking, registration, segmentation, and classification of image, where getting the original image content is vital for strong concert. While a lot of procedures are suggested for the purpose of image denoising, the issue of image noise suppression remained an open confront, particularly in situation where the images are acquire beneath poor circumstances where the noise level is very more.

**Advantages:**
- High PSNR ratio.
- More Mean to standard deviation.
- Low NAE value
- Visual appearance of enhanced image is good.

5. Results and discussions

5.1. Performance metrics

5.1.1. Peak signal to noise ratio (PSNR)

PSNR is defining in decibels. In contrast improved types, PSNR lack a capability for evaluating the relationship of an image.

\[
PSNR = 10 \log_{10} \left( \frac{MAX_I^2}{MSE} \right) = 20 \log_{10} \left( \frac{MAX_I}{\sqrt{MSE}} \right)
\]

Here,
- \( MAX_I \) is an utmost value of an image pixel.
- MSE is given by:

\[
MSE = \frac{1}{MN} \sum_i \sum_j (r_{ij} - x_{ij})^2
\]

Where \( r_{ij} \) and \( x_{ij} \) indicate pixel values of restored image and original image correspondingly and MxN is image size.
5.1.2. Normalized Absolute Error (NAE)

NAE is an estimation of how far is the reconstructed image from an original image, with zero value being a perfect fit. A big value of NAE show a low image quality then a tiny value shows a high-quality image.

This quality measure can be expressed as follows.

$$NAE = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} |A_{ij} - B_{ij}|}{\sum_{i=1}^{m} \sum_{j=1}^{n} A_{ij}}$$

A higher NAE value shows that image is of poor quality.

![Figure 3: Input Image](image1.png) ![Figure 4. Lab Color space](image2.png)

The above figure 3 represents an input image from FOREST dataset which was considered for the study. Figure 4 shows the lab color space of an input. LAB color space is particularly useful on behalf of boosting colors and definition in images due to the way it handles colors when compared to RGB and CMYK. Rather than describing how colors should appear on a screen or in print, LAB is designed to approximate human vision.

Figure 5 and 6 shows the inverted image and de-hazed image respectively. The excellence of image considered beneath bad visibility is constantly ruined by the existence of fog, haze, smog or mist. As the atmosphere was influenced image contrast is very much decreased. Dehazing is the procedure of eliminating haze from a captured image. During the past decade many researchers have devoted on the trouble of how to get high quality dehazed image.

Black and white image inversion mentions to an image processing method where light regions are mapped to dark, and dark regions are mapped to light. In additional words, afterimage inversion black turns to white then white altered to black. Figure 7 refers to the Inverting the Results as shown below.
Figure 7 Inverting the Results

Figure 8. Increasing the Saturation

Image saturation is a conception preferred to portray the intensity of color in an image, like an image with very less saturation approaches a black in addition to white image. Pink, then, is supposed to be less saturated than red for the reason that in a pure red color, the red totally dominate further color components, and hues of grey are thought to be de-saturated as all the color components give uniformly to the shade. Here, figure 8 shows the increasing the saturation of the inverted dehazed image.

Image denoising mentions to the revival of a digital image that is contaminated with noise. The occurrence of noise in images is inescapable. It could be introduced throughout image formation, recording or transmission stage. Additional processing of the image frequently needs that the noise should be eliminated or at least decreased. Figure 9 shows the denoising of the saturated image.

Figure 9. De-noised image

Figure 10. Illuminated Image

Figure 10 shows the input as well as illuminated image and figure 11 shows the final output image by applying An enhanced adaptive HE based local contrast preserving technique.

Figure 11. Output Image

Validation

In this study five datasets are considered for analysing the results viz., ARCH, FOREST, PUPPET, TIME and TATE. The Comparison of existing and proposed result of various datasets is as shown in
below given table 1. From the achieved results it is clear that the results of proposed is enhanced compared to the existing method.

| Dataset | Input Image | Existing Result | Output Result |
|---------|-------------|-----------------|---------------|
| ARCH    | ![Image](image1) | ![Image](image2) | ![Image](image3) |
| FOREST  | ![Image](image4) | ![Image](image5) | ![Image](image6) |
| TIME    | ![Image](image7) | ![Image](image8) | ![Image](image9) |
| PUPPETS | ![Image](image10) | ![Image](image11) | ![Image](image12) |
| TATE    | ![Image](image13) | ![Image](image14) | ![Image](image15) |

5.1.3. Natural Images

This sub-section deals with the validation of parameters of natural images such as PSNR and NAE of the existing and the proposed method. The graphical representation of PSNR and NAE is shown in figure 12 and 13.
Table 2. Comparison of Parameters of existing and proposed methods

| DATASET | PSNR | NAE | DATASET | PSNR | NAE |
|---------|------|-----|---------|------|-----|
| FOREST  | 53.4047 | 1.0267 | FOREST | 58.3344 | 0.9949 |
| PUPPETS | 54.2289 | 1.2058 | Puppets | 58.3677 | 0.9919 |
| TIME    | 61.0154 | 2.3010 | Time    | 64.9971 | 0.9927 |
| ARCH    | 53.5091 | 1.0802 | ARCH    | 57.7374 | 0.9920 |
| TATE    | 51.6281 | 0.3452 | TATE    | 53.1415 | 0.9946 |

Figure 12. PSNR Graph

Figure 13. NAE Graph

6. Conclusion

An enhanced adaptive histogram equalization based local contrast preserving technique is advanced with the support of image processing methods and it enhanced both medical and regular or natural images which are captured in poor light conditions even during the day. The image processing methods like color spaces shift, invert images, dehazing, raise saturation etc. is used in this algorithm. Some image quality metrics such as PSNR, NAE etc. are measured to describe the efficiency of this algorithm. This metric parameter shows that the efficiency of this model is greater than other current models.

References

[1] Maini, R., & Aggarwal, H. (2010). A comprehensive review of image enhancement techniques. arXiv preprint arXiv:1003.4053.
[2] Lim, J. S. (1990). Two-dimensional signal and image processing. ph.
[3] Gonzalez, RC, and Wintz, PA (1987). Digital Image Processing. Reading, MA: Addison-Wesley
[4] Parihar, A. S., Singh, K., Rohilla, H., Asnani, G., &Kour, H. (2020, May). A Comprehensive Analysis of Fusion-based Image Enhancement Techniques. In 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS) (pp. 823-828). IEEE.
[5] Jia, Y., & Zhang, W. (2020). Efficient and Adaptive Tone Mapping Algorithm Based on Guided Image Filter. International Journal of Pattern Recognition and Artificial Intelligence, 34(04), 2054012.
[6] Lv, J., Deng, B., & Lu, Y. L. (2019, June). A new detail enhancement method for high dynamic range infrared image. In *Journal of Physics: Conference Series* (Vol. 1237, No. 3, p. 032060). IOP Publishing.

[7] Raikwar, S. C., & Tapaswi, S. (2020). Adaptive dehazing control factor based fast single image dehazing. *Multimedia Tools and Applications, 79*(1-2), 891-918.

[8] Mayathevar, K., Veluchamy, M., & Subramani, B. (2020). Fuzzy Color Histogram Equalization with Weighted Distribution for Image Enhancement. *Optik, 164927*.

[9] Zhou, B., Luo, Y., Yang, M., Chen, B., Wang, M., Peng, L., & Liang, K. (2019). An improved adaptive detail enhancement algorithm for infrared images based on guided image filter. *Journal of Modern Optics, 66*(1), 33-46.

[10] Shi, C., Jin, Y., Chen, Y., & Zhao, B. (2019, September). P-4.7: Image Enhancement with Visual Saturation Preserving on Adaptive Histogram Model. In *SID Symposium Digest of Technical Papers* (Vol. 50, pp. 716-719).

[11] Yang, C., Feng, H., Xu, Z., Li, Q., & Chen, Y. (2019). Correction of overexposure utilizing haze removal model and image fusion technique. *The Visual Computer, 35*(5), 695-705.

[12] Lee, J., Pant, S. R., & Lee, H. S. (2015). An adaptive histogram equalization based local technique for contrast preserving image enhancement. *International Journal of Fuzzy Logic and Intelligent Systems, 15*(1), 35-44.

[13] Dar, Khursheed Ahmad and Mittal, Sumit, A Dynamic Fuzzy Histogram Equalization for High Dynamic Range Images by Using Multi-Scale Retinex Algorithm (April 1, 2020). Proceedings of the International Conference on Innovative Computing & Communications (ICICC) 2020.