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HYBRID RSWHE-POWER LAW TRANSFORMATION ALGORITHM FOR IMPROVING THE ENHANCEMENT OF THE IMAGE

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ABSTRACT

In image processing, contrast enhancement is an essential task due to the capability of improvement in image visibility. For improving the quality of the picture, the noise should be reduced, and the contrast should be high. The existing image enhancement methods do not have better performance when the model has a dark background. To overcome this issue, this paper proposes a hybrid of Recursively Separated and Weighted Histogram Equalization and Power law transformation algorithm using DWT. DWT is used for the noise reduction, and RSWHE combined with Power law transformation is used for improving the brightness of the image. RSWHE algorithm enhances the low frequency components of the image, whereas the Power law transformation enhances the high frequency components of the image. This algorithm is combined with DWT and a Wiener filter as the denoise filter, to enhance the low contrast image to high contrast with less noise and by having weighting function which smoothens each sub-histogram of pictures and also decreases the effect of increasing intensity on a color image. Results illustrate that the proposed hybrid RSWHE-Power law transformation using DWT has improved performance in the image enhancement of the dark image. The contrast of the input image is highly improved with the proposed technique.

Keywords: recursively separated and weighted histogram equalization, contrast enhancement, discrete wavelet transform, denoise filter.

1. INTRODUCTION

In digital image processing, image contrast enhancement is an essential task. The ultimate aim of the image enhancement is the production of an image with better quality as well as the improvement in the interpretability. In the image enhancement process, the input image pixel intensity is changed. Therefore, for a specific application, the outcome is more appropriate than the original image, and the visibility of the output image is better compared with the other traditional methods (Bhandari *et al.* 2011).

The broad applications of image enhancement are medical images, iris detection, fingerprint identification and face recognition (Agarval and Mahajan 2017). By using the image enhancement, the visual quality of the image can be enhanced. The main reasons behind the quality degradation are deficient in operator expertise and image capturing equipment quality. Usually,images are taken in dark, bright and wild environments. Suppose, if the imageis taken in too dark and too bright surrounding, then it is necessary to enhance the image for better visibility. Additionally, transmitting and scanning of an image from one spot to another spot may distort the image. The brightness difference may occur due to the non-uniform illumination which also demands enhancement (Rahman *et al*. 2016).

For a simple and efficient image enhancement Histogram equalization (HE) is mostly used. The intensity of the image pixels is divided in HE based on the entire image information. In many cases mean shift problems occurs. So, HE cannot guarantee the preservation in the brightness. And also, the major drawback of the HE is that it diverges brightness level mean of the image until the middle range of the dynamic level. This causes saturation in intensity and over image enhancement. Brightness preserving bi-histogram equalization (BBHE) is a developed form of HE, and it produces improved results compared with HE. BBHE preserves the original image. However, the results are not evident in BBHE when asymmetrical image distribution is applied. Dualistic sub-image histogram equalization (DSIHE) method decreases the drawback of the BBHE by separating the histogram followed by the image median.

To solve this over enhancement problem Recursive Mean Separate Histogram Equalization RMSHE (Krishna Prasad, K., & Aithal 2017) and Recursive Sub Image Histogram Equalization RSIHE were proposed (Paul *et al*. 2017).These RMSHE and RSIHE were implemented based on the same principle. However, for segmentation the threshold value by the mean and median value was different. Compared with RMSHE method, RSIHE had more preservation in brightness. After the r^{th} recursion 2r sub histograms were generated, here r is a natural number. So, to find the best valuer is a significant concern. To solve this problem a Recursively Separated and Weighted Histogram Equalization (RSWHE) based algorithm was proposed for the image enhancement and also to provide preservation in image brightness.

From the details as mentioned above, it is understood that the HE based image enhancement methods affect the quality of the image under and over enhancement. The image preservation brightness also one of the significant problems in the existing image enhancement methods. To overcome these problems in image enhancement, this paper proposes a modified RSWHE algorithm with DWT for enhancing the high contract in the image. The histogram is used for the image enhancement. The high contrast-enhanced image is implemented through the low-quality image with the help of proposed modified RSWHE algorithm with DWT.

This paper is organized as follows: Section 2 Represents the Literature review, Section 3 describes the proposed modified RSWHE based DWT algorithm, Section 4 discusses the results, and Section 5 gives the conclusion.

2. LITERATURE REVIEW

This section reviews the various image enhancement techniques already available in this field.

Agarval and Mahajan (2017) proposed a Quad Weighted Histogram Equalization with Adaptive Gama Correction and Homomorphic Filtering (QWAGC-FIL) approach for the enhancement of the medical images. This approach preserved the maximum level of entropy with the enhancement control. This method integrated the HE with Weighted Probability Distribution, Homographic filtering, and HGC for the better entropy preservation performance.

Deivalakshmi *et al.* (2017) proposed a Raised Cosine Adaptive Gamma Correction (RC-AGC) method for the enhancement of video and image. By using this RC-AGC, the cosine envelope smoothness was improved.

Dhal and Das (2017) presented a method based on the combination of Otsu segmentation method, WTHE, and CS. The use of the Otsu method enhanced the preserve brightness of the image. In this proposed method, initially, a histogram of the image is separated on the threshold range. For the modification of lower and upper histogram values weighing constraints were formulated. Finally, WTHE and CS were united for the enhancement of the image.

Hussain *et al*. (2018) proposed a local transformed histogram method for the enhancement of the dark image. Compared with the other techniques the proposed method had better performance. Because this transformation method did not apply to the entire portion of the image. This transformation method was employed for the small section of the input image. Therefore, it was not affected by the over-enhancement problem. The results have shown that the higher performance of transformation method compared with the existing methods.

Lai *et al*. (2017) presented a local histogram equalization technique based on the modification of cumulative distribution function in the sub-images. The input image was first separated into non-overlapped sub-images including the partition approach for time complexity reduction. Local histogram equalization technique was applied for the creation of the overlapped sub-image creation. For the reduction of under and over enhancement, bilateral Bezier curve was modified for very sub-image.

Liu *et al.* (2017), proposed two image enhancement methods namely SPHOE and CSPOHE for effect of the environmental contrast enhancement. For that stratified sampling concept was adopted for the approximation of distribution enhancement. From the experimental results, it was identified that the proposed CSPOHE has the ability for providing better contrast, artifact-free and high processing efficiency. This proposed method can be used for pattern recognition, surveillance and biometric analysis system.

Parihar (2017) presented a fuzzy theory-based algorithm for contrast enhancement. For that Fuzzy Contrast Distribution (FCD) was introduced. For the calculation of FCD fuzzy rules and fuzzy membership functions were framed. There was no requirement for parameter tuning in the proposed algorithm. For testing, the performance of the presented method large number of images was used. The results were evaluated visually and quantitatively. The visual and quantitative assessment of these results displayed that the proposed algorithm outperformed state-of-the-art algorithms and conventional for the images.

Tiwari *et al*. (2018) introduced moving average-based histogram modification filter (MAHMF) method for solving the fewer enhancement problems in grey levels. This filter worked from pre-processing in HE based methods. The outcomes showed the performance improvement in the HE based systems.

Zhuang & Guan (2017) proposed a Dualistic Sub Image Histogram Equalization (DSIHE)

Technique constructed on the median value for the segmentation. Comparing with the BBHE, the proposed DSIHE has the better performance in the brightness preservation with image information. For preserving the maximum brightness, a Minimum Mean Brightness Error by Histogram Equalization (MMBEBHE) method was introduced (Kansal *et al*. 2017). Based on the threshold level of the segmentation the MMBEBHE resulted in minimum value in the brightness error.

3. PROPOSED METHODOLOGY

A. Discrete Wavelet Transform

Discrete Wavelet Transforms (DWT) is used for the modification of images from the spatial domain to the frequency domain (Srivastava & Khare 2017).

Main wavelength functions are represented by the small wavelet information that is the home function coverage. For the retrieval of the information from a various signal levels low pass and high pass, filters are passed in the small wavelet transform. This wavelet provides multi-resolution capability and better energy compression. In term of color density, the wavelet is a stable one, and it provides adequate information about the shape and texture of the image. The calculation time is decidedly less in small wavelet transform and the efficiency also high (Ashraf *et al.* 2018). Further DWT is decomposed for obtaining the signal by using the wavelet functions and base functions. Subsampling and recursive filtering are the multi-resolution methods which are used in two-dimensional wavelet transformation. The levels are represented in the discrete wavelet transform, and it decomposes the image into four different sub-band frequencies as LL(low-low), LH(low-high), HL(high-low) and HH(high-high). Here, L represents Lower frequency and H represents a higher frequency.In this paper, the Daubechies 2 wavelet (dB2)wavelet is used for the

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calculation of image characteristics.dB2 is very fast in calculations, and it has better performance (Bhosale & Kanade 2017). The dB2 wavelet accelerates the process of wavelet calculation in an n-number of sliding windows in different sizes of the image.

B. Description of RSWHE

Low frequency components of the image have the essential attributes of the image. The DWT transformed low frequency components of the image are processed using RSWHE algorithm. In the histogram equalization mean RSWHE solves the shift problem. The RSWHE recursively decompose the image instead of only one-time decomposition. RSWHE improves the preservation and enhancement of the image brightness. In RSWHE, before the equalization process, the input histogram is changed. There are three modules are involved in the RSWHE process. The modules are:

- Histogram segmentation
- Histogram weighting
- Histogram equalization

a) Histogram segmentation

In the histogram segmentation, based on the mean and median values image is recursively split into two or more sub histograms. Consider an input image as X and recursively divide them in the histogram input H(X) and produced 2r sub-histograms up to some certain recursion level r (Kim & Chung 2008). Two types of segmented values are produced in this segmentation module namely means of the sub-histograms and medians of the sub-histograms.

i. Segmentation by mean

Consider a divided histogram $H^t(X)$ characterized over a dim level range [X_l, X_u].at a recursion level t (0 ≤ t < r). The mean X_M^t of the sub-histogram $H^t(X)$ is calculated by (1),

$$X_M^t = \left[\sum_{k=l}^{u} kP(k)\right] \Big/ \left[\sum_{k=l}^{u} P(k)\right] \tag{1}$$

Followed by the computed mean X_M^t, the histogram $H^t(X)$ is then separated into two sub-histograms $H_L^{t+1}(X)$ and $H_U^{t+1}(X)$ for the further recursion level t+1, where $H_L^{t+1}(X)$ and $H_U^{t+1}(X)$ are defined over [X_l, X_M^t] and [X_M^{t+1}, X_u], correspondingly.

ii. Segmentation by median

Assume that the Cumulative Distribution Function (CDF) at the grey level X_l is c(l) = ml, and the CDF at the gray level X_u is c(u) = mu. The median X_D^t of the sub-histogram $H^t(X)$ then satisfies c(X_D^t) = $\frac{m_l + m_u}{2}$ .Generally, the median X_D^t t is calculated from (2),

$$X_D^t = \arg\min_{l \le k \le u} \left| c(k) - \frac{m_l + m_u}{2} \right| \tag{2}$$

Now, the histogram $H^t(X)$ is divided into two sub-histograms $H_L^{t+1}(X)$ and $H_U^{t+1}(X)$ for the further recursion level t+1 by using X_D^t . Note that $H_L^{t+1}(X)$ and $H_U^{t+1}(X)$ are defined over[X_l, X_D^t] and [X_D^{t+1}, Xu], individually.

b) Histogram weighting

The histogram weighting module changes the standardized power law function of the sub histograms. Based on the specified recursion level r, 2r sub-histograms are generated by the histogram segmentation $H^r_i(X)$ (0 ≤ i ≤ 2r - 1).
Where, H^r_i (X) is defined over the range [X_l, X_u].

The histogram $^r{}_{weighting}$ module modifies the sub-histograms Hri(X) is given in the following steps

a) the highest probability p_{max} and the lowest probability p_{min} are computed by using the equations (3) and (4),

$$p_{max} = \max 0 \le k \le L-1 \ p(k) \tag{3}$$

$$p_{min} = \min \ 0 \le k \le L-1 \ p(k) \tag{4}$$

b) For every sub-histogram $H^r_i(X)$, an accumulative probability value $\alpha_i$is computedby using the equation (5) and (6).

$$\alpha_i = \sum_{k=li}^{ui} p(k) \tag{5}$$

$$\sum_{i=0}^{2r-1} \alpha_i = \alpha_0 + \alpha_1 + \alpha_2 + \ldots\ldots + \alpha_{2r-1} = 1 \tag{6}$$

c) Histogram equalization

The histogram equalization module separates each of the modified sub-histograms. The PDF $p_{wn}(k)$ consists of 2r curve segments, where the i-th curve segment (0 ≤ i ≤ 2r - 1) is bounded by the same range [X_l, X_u] as that of the i-th sub histogram $H^r_i(X)$. The main function of histogram equalization module is to equalize each of all 2r sub histograms separately. The combination of all resultant sub-images now becomes the final output image.

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C. Power Law Transformation algorithm

The DWT transformed high frequency components of the image are processed using Power law transformation algorithm. The basic form of the transformation is as follows.

$$P = Sr^{\gamma}$$

where S and r are positive constants. In log transformation, power law curves are formed using $\gamma < 1, \ldots$

For $\gamma < 1$, a narrow range of dark input values are mapped into a wider range of output values and with the opposite being true for higher values of input. By varying this γ, a family of possible transformations are obtained. And the reverse mapping and transformation processes happens for $\gamma > 1$.Gamma correction is extremely essential as the use of digital images for commercial purposes over the internet has increased. The value of γ varies according to the type of the device used for capturing, printing, or displaying the image. And accordingly, the power law transformation will respond.

D. Denoise Filter

In the image processing task image denoising is an essential one. One-dimensional images and geometrical images are described in the denoising method. For denoising the image many methods are used. In image denoising, different types of noises are achieving by Mean filter, Median filter and Wiener filter. The denoise filter used for noise elimination and edge preservation in this proposed methodology is the Wiener filter.

E. Proposed Hybrid RSWHE - Power Law Transformation Algorithm Using DWT

To enhance the high contrast of image hybrid RSWHE - Power law transformation algorithm using DWT is introduced. This proposed methodology uses image histogram for achieving better enhancement. The primary limitation of the image enhancement is the background contrast losses in the small regions. The parameters such as mean, median values, noise level are considered in the proposed algorithm. Figure 1 represents the block diagram of the proposed hybrid RSWHE - Power law transformation algorithm using DWT.

Initially, an image to be enhanced is selected. Then using the DWT, the original image is decomposed into low-frequency (LF) and high-frequency (HF) components. These LF and HF components describe the frequency components approximation which covers the entire frequency spectrum of the original image.

To generate the different image frequency, the filter bank is needed for the original image operation. Based on the identification of these images edges of high frequency is calculated in low frequency and these values are considered as wavelet coefficients.

Enhancement of the low-frequency components is done using RSWHE algorithm, which can limit the enhancement of noise effectively. For that LF component is undergoes into three processes namely Histogram segmentation, Histogram weighting, and Histogram equalization. In the Histogram segmentation, the original image is segmented the contrast area. Based on the values of the mean values of the entire segment weighted values are generated. Histogram equalization is used to match the values. This increases the contrast of the original image.

On the other hand, the high-frequency components are processed using Power law transformation. The high frequency components contain noises of that image. So, after transformation, HF components go through the Wiener filter for the removal of the noises and preserving the edges. After this process, both the LF and HF components are combined and passed through the Inverse DWT (IDWT) for the high contrast image retrieval. Then by using the adaptive filter the brightness of the image is enhanced even with the dark background.

The hybrid RSWHE-Power law transformation algorithm steps are followed as:

Step 1: Select the input image (X)

Step 2: Using DWT split into LF and HF components

Step 3: LF component is given as the histogram input H(X)

Step 4: Produce 2^r sub-histograms to the recursion level r.

Step 5: Compute mean X_M^t using (1) in the level of [X_l, X_u] at a level of [$0 \le t \le r$]

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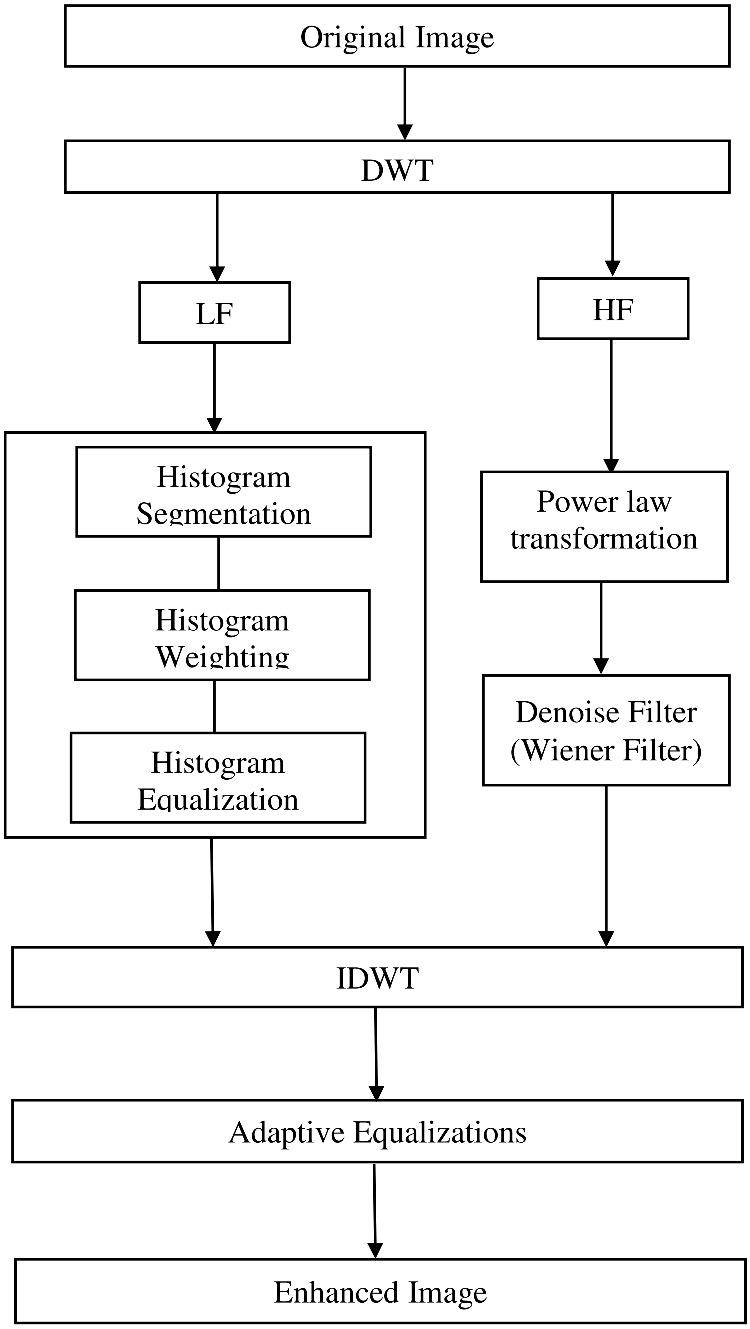

Figure-1. Block diagram of the hybrid RSWHE-Power law transformation using DWT.

Step 6: Then $H^t(X)$ is separated into $H_L^{t+1}(X)$ and $H_U^{t+1}(X)$ for further recursion

Step 7: Compute median value using the equation (2)

Step 8: Compute the histogram weighing function using $H_i^r(X)$

Step 9: Find highest and lowest probability p_{max},p_{min} respectively.

Step10: For every sub-histogram compute an accumulative probability value α_i

Step 11: Histogram module separates the modified sub-histograms

Step 12: Power law transformation is done over the HF components

Step 13: After transformation, the noise in the image is removed by the denoise filter

Step 14: After histogram equalization apply IDWT process on LF and HF components.

Step 15: Enhance the brightness by using adapt equalization

Step 16: Get the enhance image at the output

3. RESULTS AND DISCUSSIONS

Figure 2 shows the input image taken for the enhancement process. The aim of this task is to improve the brightness of this image with the hybrid RSWHE-Power law transformation algorithm using DWT.

Figure-2. Input image.

In the MATLAB programming, the input image is loaded and resized. Then this image is applied through the DWT transformation. After using the DWT process, the input image is split into four bands which are shown below Figure-3.

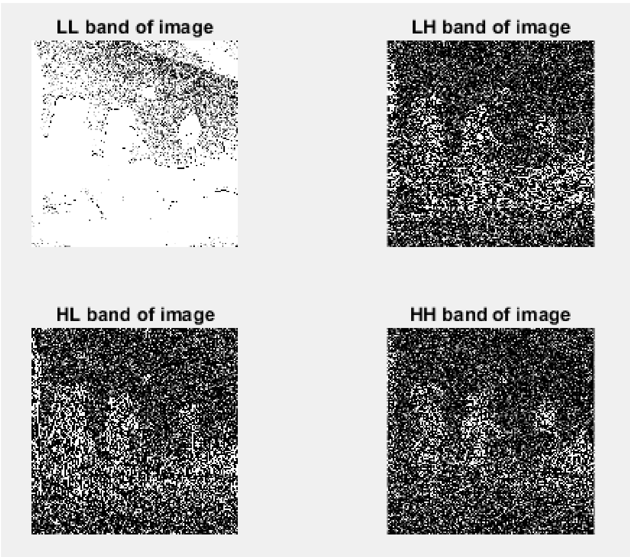

Figure-3. Image after DWT transformation.

Among the four bands in the above process, the low-frequency image is selected, and it is illustrated in Figure-4.

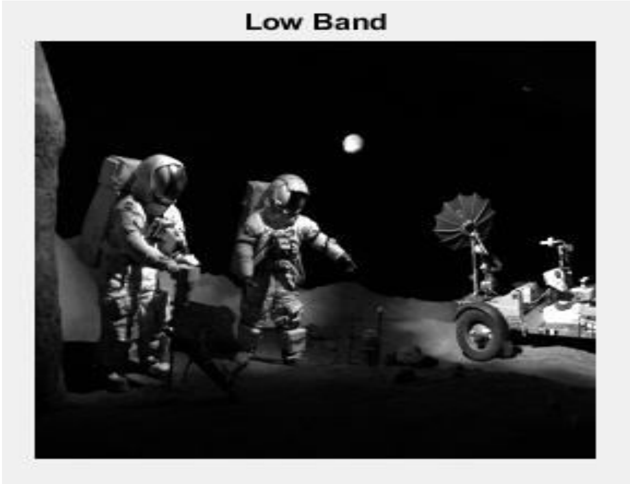

Figure-4. Low band image.

Then RSWHE algorithm is applied as in the following three stages Histogram Segmentation, Histogram Weighting, and Histogram Equalization. These three stages are employed in the low band frequency only.

The other three bands from the DWT is applied to the denoise filter for the reduction in noise. In this proposed approach wiener filter issued for the denoise process as shown below in Figure-5.

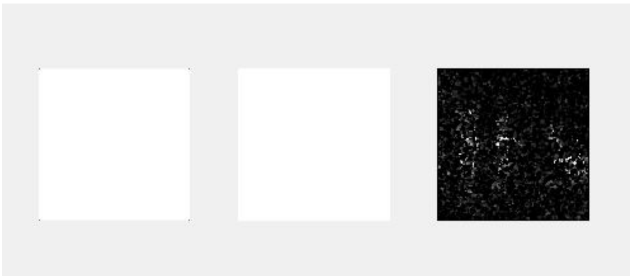

Figure-5. Image after using wiener filter.

Finally, for the reconstruction of the image IDWT is used for the image retrieval process. Then the reconstructed image is employed to the adapt histogram equalization. By using the MATLAB command adapt hist eq, the contrast image transfer function is calculated for entire time individuality. This enhances each tile's in the histogram output region. This approximately matches the histogram specified by the 'Distribution' value. The figure.6 shows the comparison of the original image with the final reconstructed image. From this, it is identified that the reconstructed image has better brightness than the original image.

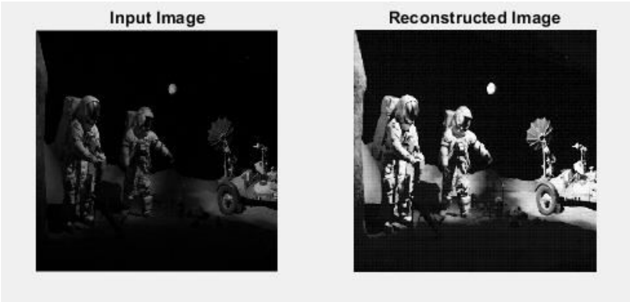

Figure-6. Comparison of original image with the reconstructed image.

The Table-1 shows the results of the parameters defining the image quality of the proposed image enhancement technique with other existing algorithms namely, Dynamic Histogram Equalization (DHE) [10], Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE) [11] and Histogram Equalization (HE) [1-6]. The results tabulated in the comparison table infer that the performance parameters such as Entropy, Contrast, Mean Square Error (MSE), Standard Deviation(SD) and Normal Cross Correlation(NCC) of the proposed image enhancement technique are better than existing algorithms DHE, BPDFHE, and HE.

Table-1. Comparison of results of the proposed method with existing algorithms.

	Entropy	**Contrast**	**MSE**	**Standard**	**NCC**
DHE	5.242656	0.584281	0	34.61158	1
BPDFHE	4.787238	0.555551	36.87893	31.67057	0.82325
HE	4.515719	0.698231	3.442948	67.43832	2.816748
Proposed	6.255265	0.920441	0.21267	77.61559	2.900662

The simulation results of the proposed method are compared with the existing methods and are tabulated in the Table-2.

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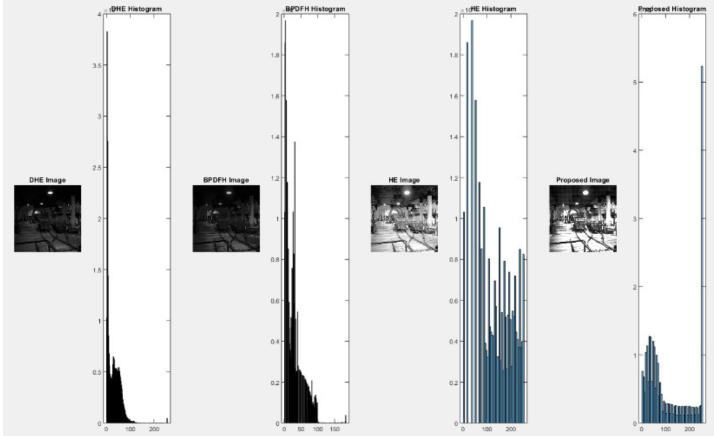
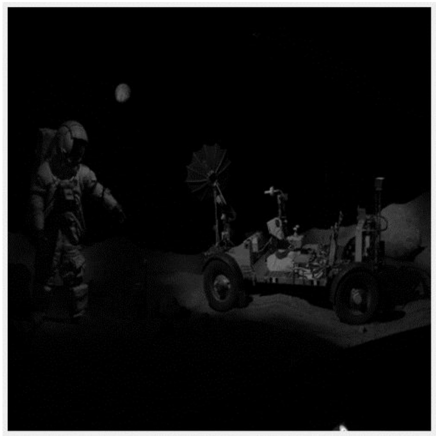
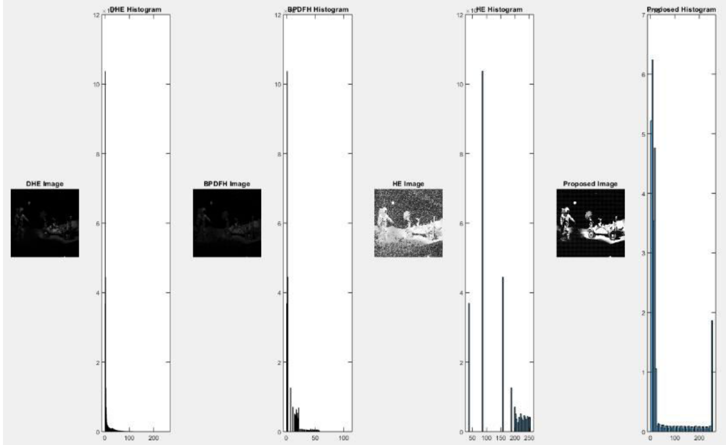
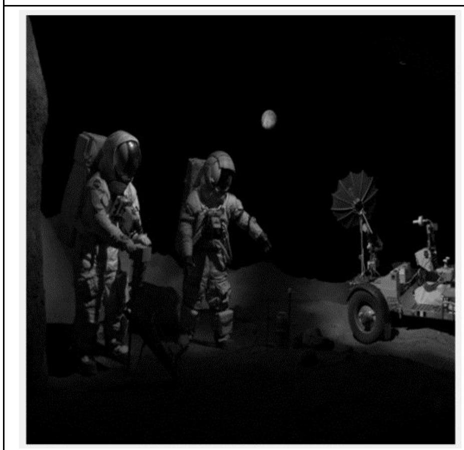
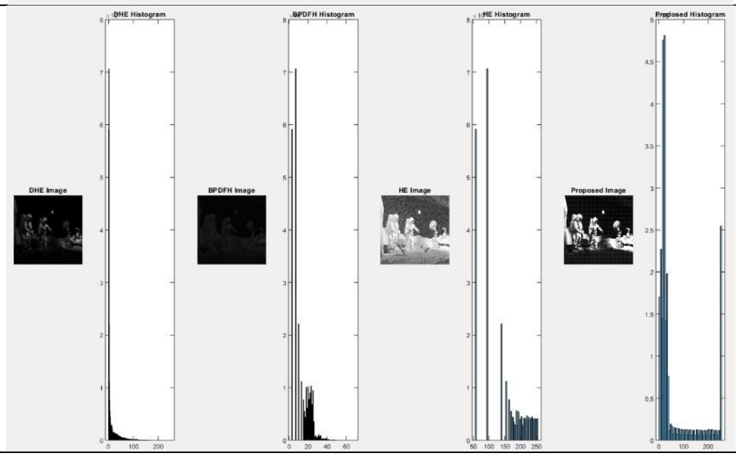
Table-2. Comparison of simulation results of image quality enhancement.

Input Image	Comparative Results of Image Quality Enhancement
	
	
	

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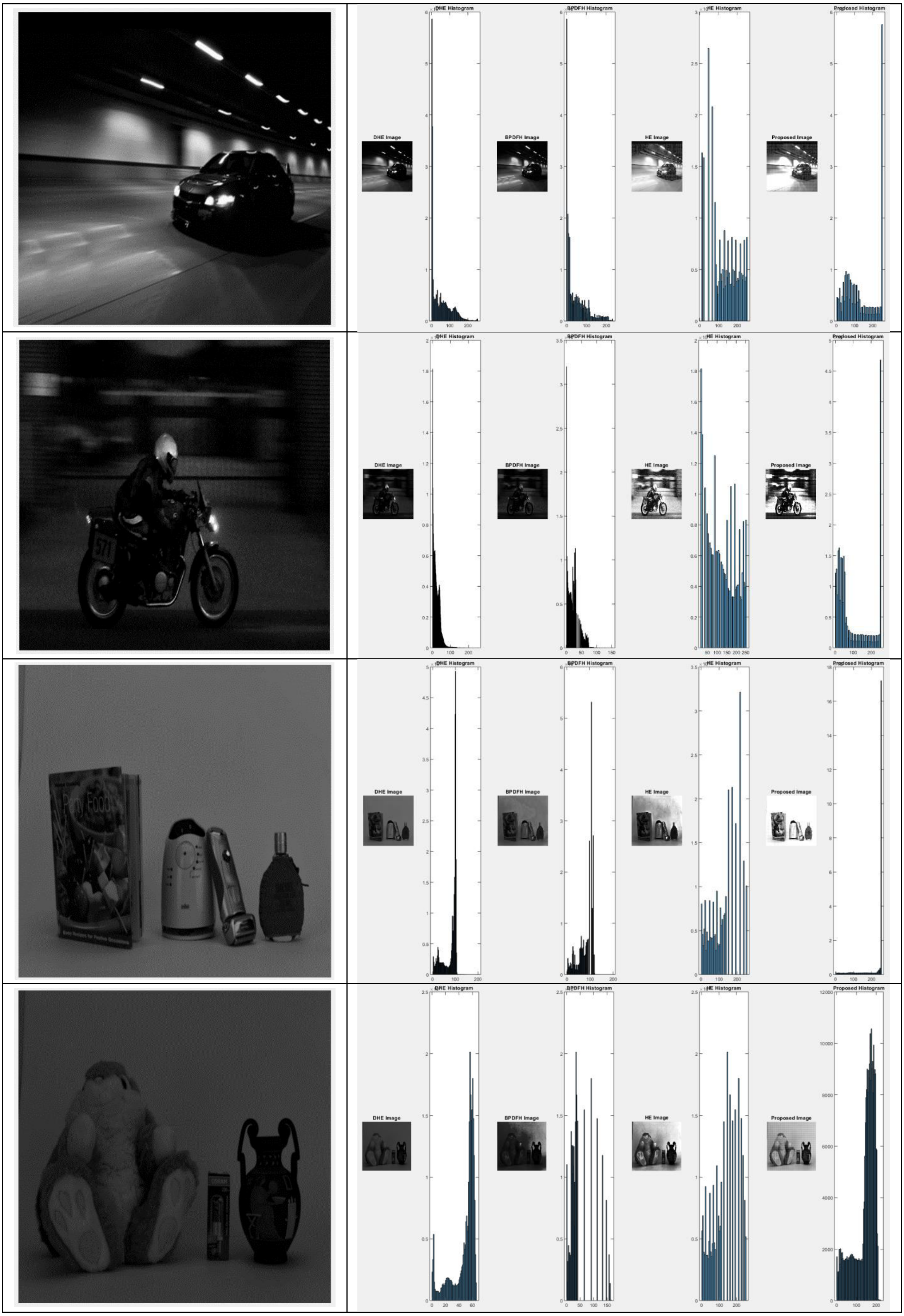

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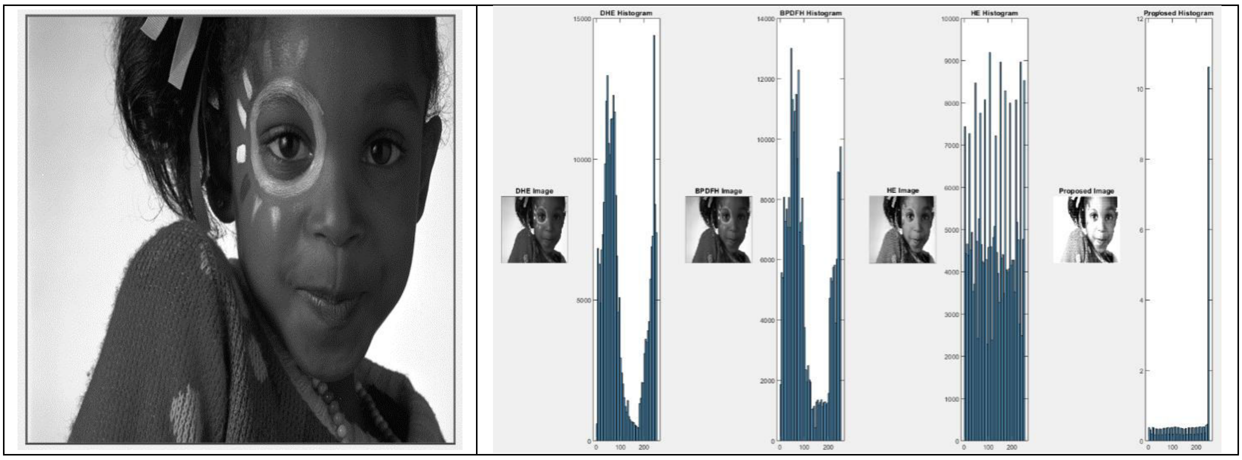

It is evident that the histogram profile of the proposed method is better compared to other existing image enhancement techniques. Thus the simulation resultant images in the table illustrate the superior performance of the proposed method over the existing methods namely, DHE, BPDFHE, and HE.

5. CONCLUSIONS

This paper had proposed hybrid Recursively Separated and Weighted Histogram Equalization-Power law transformation algorithm using DWT. DWT was used for the noise reduction, RSWHE and Power law transformation algorithms are used in combinationfor improving the brightness of the image. By combining DWT and the hybrid RSWHE - Power law transformation algorithm along with denoise filter, enhanced low contrast image to high contrast with less noise can be obtained. Weighting function smoothens each sub-histogram of images and it has decreased the effect of increasing intensity on a color image. Results showed that the proposed hybrid RSWHE-Power law transformation algorithm using DWT has the better performance in the enhancement of a dark image. The brightness of the input image was highly improved with the proposed hybrid RSWHE-Power law transformation algorithm using DWT. In future, this proposed algorithm can be used for fusion in a medical image like CT and MRI for better enhancement.

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