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An Optimal Gamma Correction Based Image Contrast Enhancement Using DWT-SVD

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Abstract- In this paper, an improved image contrast enhancement algorithm using Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) with optimal gamma correction is proposed. The input image is decomposed into four sub band images using DWT, and only Low-Low (LL) sub band image is chosen for processing to avoid possible degradation of edge information while processing. By applying SVD, singular value matrices of input image and histogram equalized image's LL sub bands are computed. Inverse SVD is applied on properly scaled singular value matrix of input image's LL sub band image to obtain new LL sub band image. The obtained new LL sub band image is further processed using optimal gamma correction with weighted sum in order to achieve better contrast enhancement. Inverse DWT is applied on the enhanced LL sub band image and remaining high frequency sub band images of input image, to obtain contrast enhanced output image. The proposed method is compared with Global Histogram Equalization (GHE), specified existing DWT-SVD methods, Optimal Gamma Correction with Weighted Sum (OGCWS) method. Improved performance can be achieved with proposed technique, quantitatively and qualitatively in terms of standard deviation and entropy.

Index Terms- Contrast, DWT, SVD, Gamma Correction, GHE.

1. INTRODUCTION

Now-a-days due to rapid growth in imaging devices and technology, images/videos are widely used in different engineering applications and also in communication. Computer based image processing applications are also increasing day by day. Images/videos with good contrast and brightness are required for better human perception, analysis, representation, etc. In low contrast images, maximum intensity values are concentrated over a small range; hence representation of complete information may not be possible. For better representation of the image, contrast enhancement is necessary. The high contrast image has high dynamic range with maximum details. The Histogram Equalization (HE) is widely used spatial domain method for contrast enhancement due to its simplicity; in spite of its limitations such as enhanced image with uniform probability distribution, over saturation, etc. [1]. Several spatial as well as frequency domain techniques exist in the literature for the purpose of image contrast enhancement [1-11].

SVD was used in the techniques proposed in [2-8], for the image contrast enhancement. By using SVD, a matrix with size of $M X N$ can be decomposed into the product of three matrices (an orthogonal square matrix U_{MXM}, a diagonal matrix Σ_{MXN}, and the transpose of an orthogonal square matrix V_{NXN}). SVD of an image (A) can be represented as in Eq. (1) [3].

$$A = U_A \Sigma_A V_A^T \tag{1}$$

The diagonal matrix (Σ_A), also known as singular value matrix, contains singular values on its main diagonal in sorted order. The Σ_A contains information about image intensity [12], hence any change in singular values results change in the intensity values.

In the DWT-SVD based contrast enhancement method proposed in [3], the low contrast input image and its histogram equalized image are decomposed into four sub band images named Low-Low (LL), Low-High (LH), High-Low (HL) and High-High (HH) sub bands using DWT with db.9/7 wavelet function. In order to preserve the edge details from possible degradation while processing, only the LL sub band image which contains the coarse version of the input image is chosen for processing [3]. SVD is applied on both LL sub band images. The singular value matrix of input image's LL sub band is modified by multiplying with correction factor. A new LL sub band image is obtained by using this modified singular value matrix. To obtain enhanced image, inverse DWT is applied on the new LL sub band and the remaining high frequency sub bands of the input image. The methods proposed in [5, 6] employ SVD, and DCT instead of DWT to obtain LL sub band image. An improvement in computation of modified singular value matrix to the DWT-SVD based method [3] is proposed in [4] by using both singular value matrices of input and histogram equalized image's LL sub band images.

The SVD based contrast enhancement methods depend on scaling of the singular value matrix. Although the SVD based contrast enhancement methods preserve the mean brightness, but may not produce better contrast enhancement [7]. In the literature, several improvements to DWT-SVD based methods using gamma correction are proposed [7, 8]. In the literature, Adaptive Gamma Correction (AGC) algorithms are also exist, which compute the gamma correction factor according to the given input image's characteristics [9-11]. Luminance pixels probability distribution and AGC based enhancement technique is proposed in [9]. An AGC algorithm for contrast enhancement, which computes the gamma correction parameters adaptively according to the given image's mean and standard deviation is proposed in [10]. Jiang et al. proposed a contrast enhancement method with brightness preservation using gamma correction with optimal parameters to produce enhanced images [11].

In this paper, a hybrid approach to enhance the low contrast images by using DWT-SVD technique [3] and OGCWS algorithm [11] is proposed. The proposed hybrid method gives better tradeoff between contrast enhancement and edge preservation than DWT-SVD [3] or OGCWS [11] algorithms considered separately.

2. EXISTING METHODS

The DWT-SVD based contrast enhancement technique proposed in [3] is briefly outlined here. Histogram equalized image, $\hat{A}$ is obtained by applying GHE on input low contrast image, A. LL sub band images of A and $\hat{A}$ are obtained by using DWT. By using SVD, singular value matrices of LL sub band images of both A and $\hat{A}$ ($\Sigma_{LL_A}, \Sigma_{LL_{\hat{A}}}$ respectively) are obtained. The correction factor (ξ) is obtained by the following Eq. (2) [3]:

$$\xi = \frac{max(\Sigma_{LL_{\hat{A}}})}{max(\Sigma_{LL_A})} \tag{2}$$

The modified singular value matrix ($\overline{\Sigma_{LL_A}}$) and new LL sub band image ($\overline{LL}_A$) is obtained by using the following Eqs. (3) and (4) [3]:

$$\overline{\Sigma_{LL_A}} = \xi \Sigma_{LL_A} \tag{3}$$

$$\overline{LL}_A = U_{LL_A} \overline{\Sigma_{LL_A}} V_{LL_A}^T \tag{4}$$

Inverse DWT is applied on four sub band images $\overline{LL}_A$, LH_A, HL_A, and HH_A to get enhanced image (I_E).

Based on the intensity values, the low contrast images can fall under three categories: dark (with low intensities), gray (with mid range of intensities), bright (with high intensities) [5]. The singular values depend on image intensity values, i.e., image with high intensity values has high singular values when compared with that of image with low intensity values [2]. For low intensity images $\xi > 1$, for mid intensity images $\xi \approx 1$ and for high intensity images $\xi < 1$ [5]. The correction factor, ξ =1 for images with mid range of intensities, and hence there is no considerable change in singular value matrix [4]. So, there is no significant improvement in the intensity values of the image with the method proposed in [3]. To overcome this problem, weighted sum of singular value matrices of both images ($\Sigma_{LL_{\hat{A}}}$ and Σ_{LL_A}) are considered and the Eq. (3) is modified as in Eq. (5) [4]:

$$\overline{\boldsymbol{\Sigma_{LL_A}}} = \mathbf{0.5}(\boldsymbol{\xi\Sigma_{LL_A}} + \frac{\mathbf{1}}{\boldsymbol{\xi}}\boldsymbol{\Sigma_{LL_{\hat{A}}}}) \tag{5}$$

3. PROPOSED METHOD

The specified DWT-SVD based contrast enhancement methods may preserve mean brightness well, but contrast enhancement cannot be achieved to the required extent [7]. Better contrast enhancement can be achieved by spreading the intensity values over the entire dynamic range.

To overcome this drawback, a hybrid approach is proposed by combining DWT-SVD technique [3] and OGCWS algorithm [11]. The enhanced images obtained using DWT-SVD alone may not provide better contrast enhancement, especially for images with mid range of intensities [4, 7]. In order to compensate this problem, the new LL sub band image obtained using DWT-SVD method [3], is further enhanced using OGCWS algorithm [11], to obtain enhanced LL sub band image. Inverse DWT is applied on enhanced LL sub band image and unprocessed high frequency sub band images of input image to get enhanced image.

The method proposed in [11] provides brightness preserving contrast enhancement using gamma correction with optimal parameters. The optimal parameters are automatically computed for given input image by using golden search algorithm and statistical information to provide better enhanced image [11]. Gamma correction is used for achieving better contrast enhancement and the weighted sum approach is used for brightness preservation [11].

The flow chart of the proposed hybrid image contrast enhancement technique using DWT-SVD method [3] and OGCWS [11] is shown in Fig. 1.

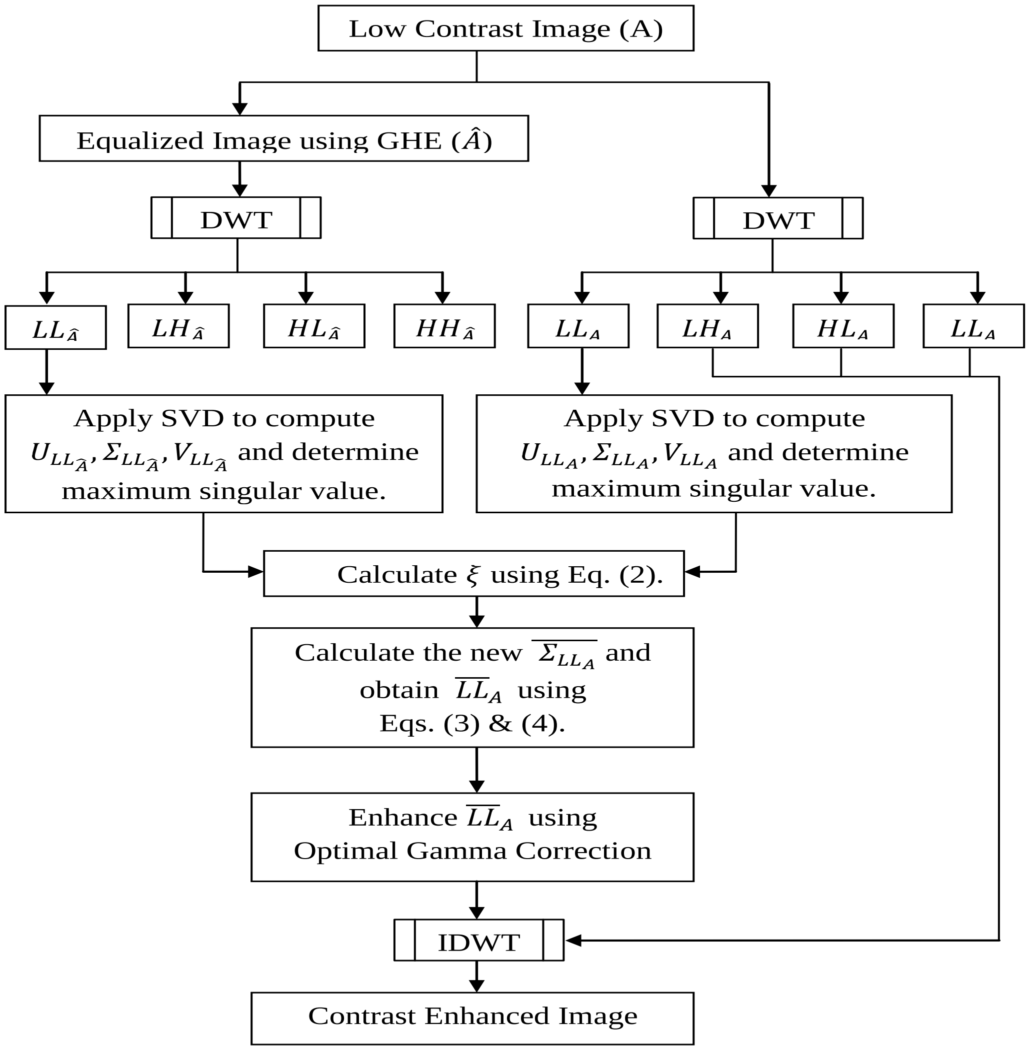


Fig.1 Flow chart of the improved DWT-SVD algorithm.

4. METRICS USED FOR PERFORMANCE ASSESSMENT

The commonly used statistical parameter for contrast assessment is standard deviation (σ). For an image (A) of size M X N, σ is obtained by using the following Eq. (6) [1]:

$$\sigma = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(A_{i,j}-\mu)^2} \qquad (6)$$

Where, μ is mean value of the image, which can be obtained by using the Eq. (7) [1].

$$\mu = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}A_{i,j} \qquad (7)$$

Quantitatively, best performance can be achieved by GHE with the above specified metric, even though its qualitative results produce visual artifacts with un-natural look [4].

The entropy value specifies the average information content in an image. The entropy value is given by the following Eq. (8) [1].

$$E = -\sum_{k=0}^{L-1} P_r(r_k)\log_2 P_r(r_k) \qquad (8)$$

Where, r_k is discrete random variable in the interval [0, L-1], occurs with a probability of $P_r(r_k)$ in an image of size M x N which is given Eq. (9) [1].

$$P_r(r_k) = n_k / MxN \text{ , k=0, 1, 2… L-1} \qquad (9)$$

Where, n_k is the number of times the k^{th} intensity appears in an image with L number of intensity values.

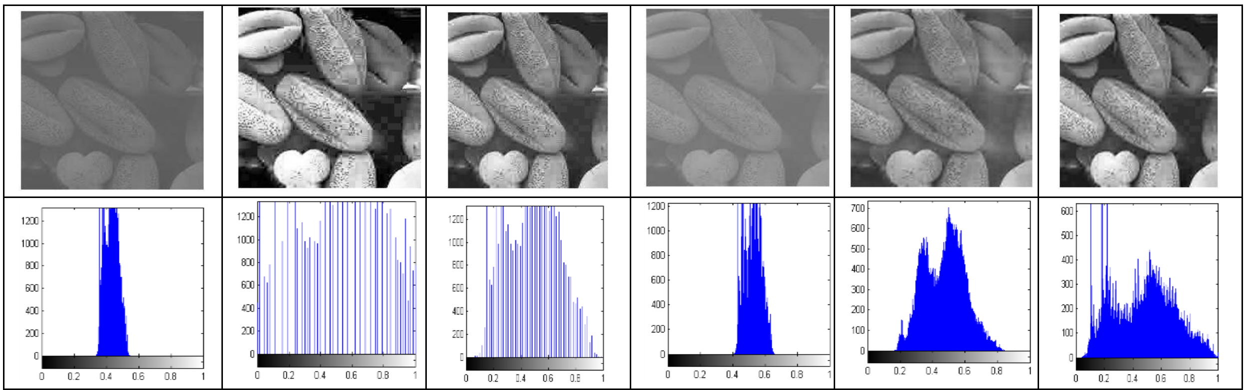
5. RESULTS AND DISCUSSION

In this paper, standard deviation and entropy values are used for quantitative analysis. The enhanced images with their corresponding histograms are given for qualitative analysis.

The enhanced images using proposed method are compared with the well known GHE, OGCWS technique [11] and specified existing DWT-SVD based techniques proposed in [3, 4].

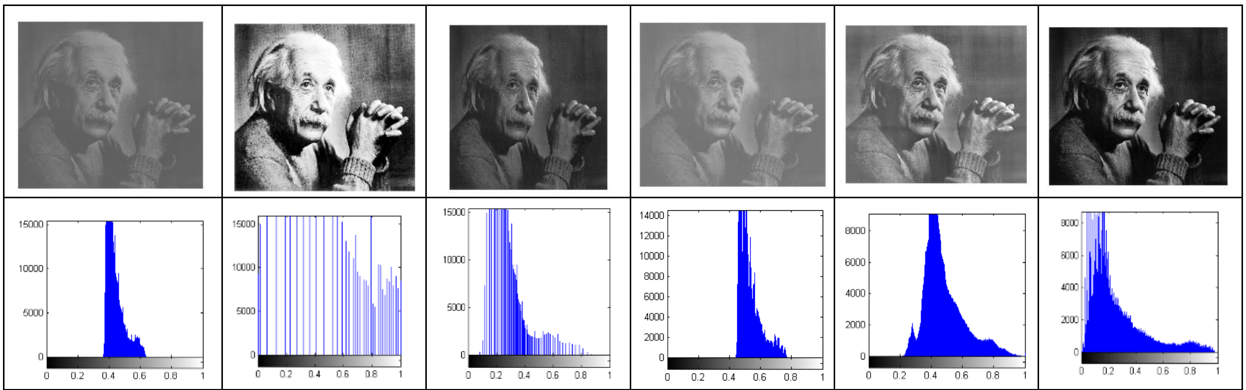
The images shown in Figs. 2 to 7 are the obtained output images with their corresponding histograms. The quantitative results such as standard deviation and entropy values are computed and tabulated in Tables 1 to 2, for images shown in Figs. 2 to 7. The low contrast input images are collected from different image databases through internet [13, 14]. The proposed method is implemented in MATLAB R2014a software and used required built in functions available in image processing tool box. Db. 9/7 wavelet function is used for implementing DWT.

From the histogram plots in Figs. 2-7, it can be observed that, the intensity values are spread within narrow range of gray scale for the input image. For the DWT-SVD based method [3] only slight difference can be observed from that of input. For the proposed method and GHE, maximum spread in intensity levels within the gray scale range are covered. Even though, there is wide spread in the intensity values for GHE, the output images are over saturated and with un-natural look, which can be clearly observed in the figures shown below. The obtained output images using proposed method are also clearer when compared with specified techniques. Considerable improvement in standard deviation and entropy values can be observed in Tables 1 and 2.



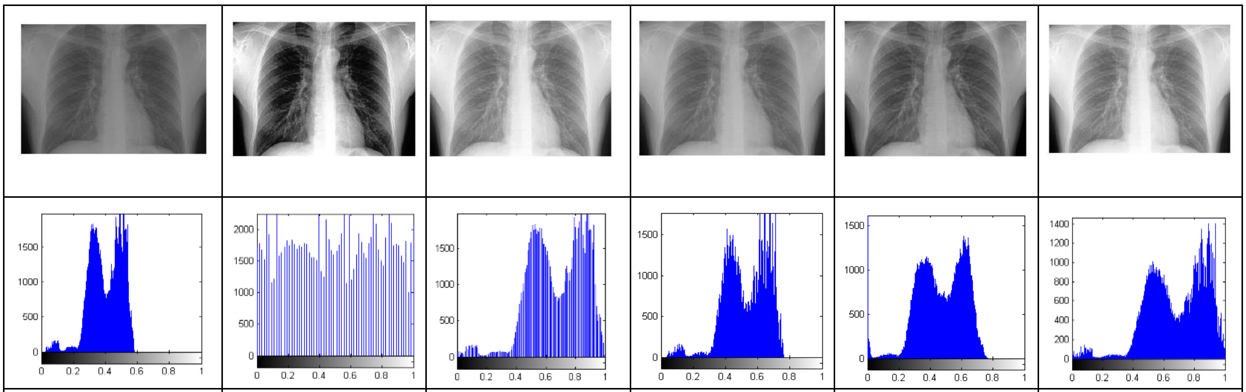
(a) (b) (c) (d) (e) (f)

Fig. 2 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method



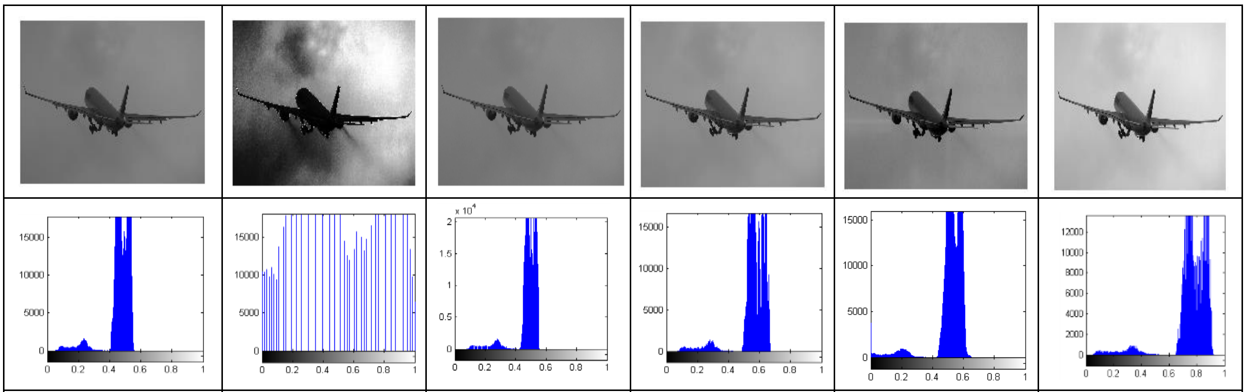
(a) (b) (c) (d) (e) (f)

Fig. 3 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method



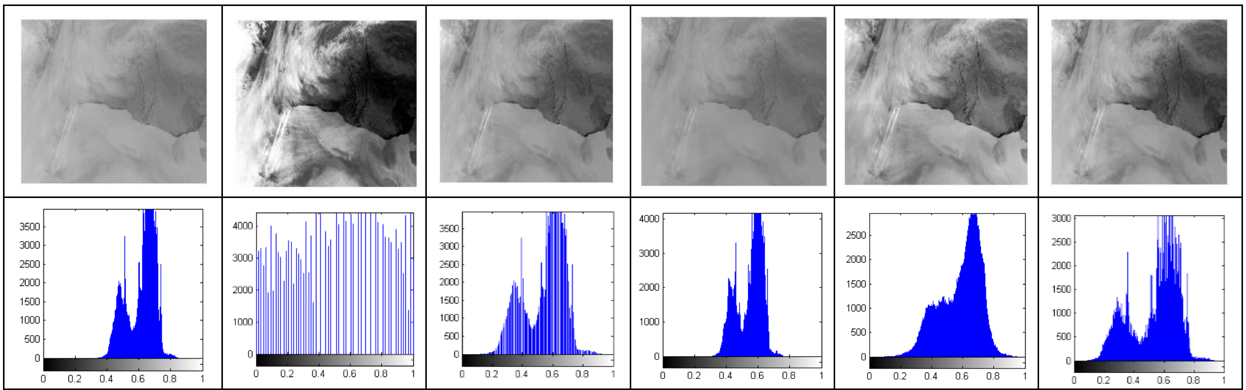
(a) (b) (c) (d) (e) (f)

Fig. 4 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method



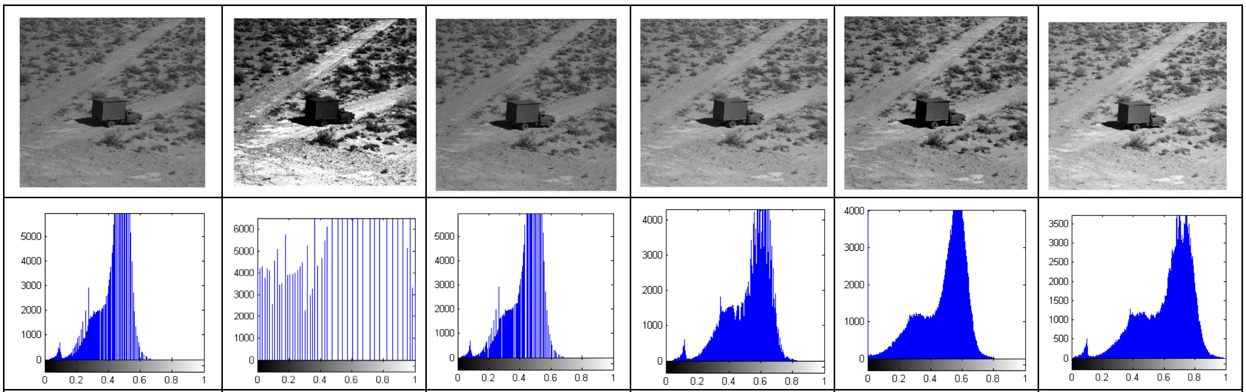
(a) (b) (c) (d) (e) (f)

Fig. 5 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method



(a) (b) (c) (d) (e) (f)

Fig. 6 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method



(a) (b) (c) (d) (e) (f)

Fig. 7 (a) Input low contrast image; and output images of different methods with their corresponding histograms. (b) GHE (c) OGCWS[11] (d) DWT-SVD [3] (e) DWT-SVD [4] (f) Proposed Method

Table. 1 Standard Deviation Values

Images in Fig. / Method	Standard Deviation (σ)					
	2 ξ = 1.2178	3 ξ = 1.2125	4 ξ = 1.3121	5 ξ = 1.2064	6 ξ = 0.8947	7 ξ = 1.2568
Input	0.0443	0.0560	0.1037	0.0812	0.0890	0.1061
GHE	0.2936	0.2953	0.2929	0.2931	0.2936	0.2929
OGCWS[11]	0.1986	0.1178	0.1902	0.0735	0.1314	0.1117
DWT-SVD [3]	0.0535	0.0678	0.1360	0.0978	0.0797	0.1325
DWT-SVD [4]	0.1272	0.1300	0.1551	0.1073	0.1351	0.1571
Proposed Method	0.2214	0.2087	0.1946	0.1455	0.1581	0.1692

Table. 2 Entropy Values

Images in Fig. / Method	Entropy Values					
	2 ξ = 1.2178	3 ξ = 1.2125	4 ξ = 1.3121	5 ξ = 1.2064	6 ξ = 0.8947	7 ξ = 1.2568
Input	5.3464	5.3519	6.4996	5.4644	6.2381	6.0274
GHE	5.2440	5.0050	5.9721	5.1450	5.6571	5.4106
OGCWS[11]	5.3464	5.3519	6.4996	5.1319	6.2381	6.0274
DWT-SVD [3]	5.6016	5.6059	6.8636	5.7109	6.0857	6.8647
DWT-SVD [4]	7.0018	6.8498	7.0574	5.7576	7.0140	7.0291
Proposed Method	7.5858	7.1573	7.3784	6.2783	7.0241	7.2375

6. CONCLUSIONS

In this paper, the problem of poor contrast enhancement of images with mid range of intensities, using scaling of singular values is eliminated by using proposed method. The proposed method is compared with GHE, OGCWS and specified existing DWT-SVD based methods. Standard deviation and entropy values are used for quantitative analysis. Obtained output images with their respective histogram plots are also compared. From the results it is evident that the proposed method achieves improved results.

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