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An Improved Image Contrast Enhancement using Multi Resolution Singular Value Decomposition

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Abstract

SVD has several attractive features like less computational complexity, low rank approximation, etc. Hence in recent days, SVD became an attractive algebraic transform for different image processing applications. In literature, several techniques for image contrast enhancement based on Discrete Wavelet Transform and Singular Value Decomposition, are proposed. This paper presents a technique for gray scale image contrast enhancement by using Multi Resolution Singular Value Decomposition. The performance of this algorithm is compared with that of image contrast enhancement technique based on DWT-SVD. Mean and Standard Deviation are computed for objective analysis. The proposed method gives improved performance subjectively, and objectively in terms of standard deviation.

Keywords: Contrast, Discrete Wavelet Transform, Multi Resolution Singular Value Decomposition.

INTRODUCTION

Fourier Transform (FT) is used as the basic tool in signal processing and analysis, which approximates the signal in terms of sinusoids. One of the limiting factors of FT is that it is not well suited for non-stationary signal processing. Several alternatives exist in literature to solve this problem, such as Short Time Fourier Transform, Wavelet Transform etc. Discrete Wavelet Transform (DWT) is the most powerful and frequently used transform among these alternatives. The usage of DWT is limited due to conceptually complex structure, need of huge computational memory due to usage of filters and perfect reconstruction is limited to some specified degree [1]. To deal with non stationary signals, an adaptive image transform approach is more preferable than fixed transforms [2]. One of the possible solutions to these issues is the Multi Resolution Singular Value Decomposition (MR-SVD) which is very simple and has perfect reconstruction [1]. MR-SVD does not have fixed set of basis vectors like Fast Fourier Transform, Discrete Cosine Transform (DCT) etc. It is data dependent adaptive transform. In the past few years, MR-SVD has been used in some of the image processing applications like image denoising [3], image fusion [4], image compression [1] etc. This paper presents an application of MR-SVD to image contrast enhancement.

The purpose of image enhancement is to obtain better quality image for a specific application by increasing the given image quality. Image contrast enhancement is an important primitive operation in image processing for better human perception and computer vision. Image contrast is one of the image quality measures, which is defined as the difference in intensity between highest and lowest intensity levels in an image [5]. In the images with low contrast, all information is intense over a narrow range resulting loss of information in the remaining areas [6]. To represent all information present in an image contrast improvement is required. The high contrast image has high dynamic range with more gray level details. There exist different techniques in literature for image contrast enhancement. The Global Histogram Equalization (GHE) technique is commonly used for image contrast enhancement because of its simplicity. The GHE remaps the input image gray levels based on its probability distribution resulting uniform probability distribution irrespective of the form of the input probability distribution function (PDF) [5]. It is useful for image with poor intensity distribution, but it over saturates several areas of the image. The GHE cannot be applied for some applications, where PDF shape preservation is important [6].

On the other hand, DWT or DCT with SVD has been used for image contrast enhancement [7]-[10]. Different applications of SVD in the area of image processing such as image denoising, image forensic, image compression etc., were discussed in [11]. SVD of an Image (A) of size $M X N$ can be represented as shown in Eqn.1.

$$A = U_A \Sigma_A V_A^T \qquad (1)$$

Where, U_A is an orthogonal square matrix of left singular vectors, Σ_A is a diagonal matrix which contains singular values in sorted order on its main diagonal, and V_A is an orthogonal square matrix of right singular vectors.

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Multi Resolution Singular Value Decomposition

(MR-SVD)

In [12], Kakarala proposed multi resolution form of SVD by retaining the properties of SVD. The basic idea behind their approach of MR-SVD is to replace low pass and high pass filters used in wavelets with SVD at each level of approximation. The steps involved in obtaining MR-SVD for 2-D images are as follows [12]:

Let A represents an image of size M X N such that M and N are dyadic.

- Segment A into non overlapping blocks of size p X q. (let $p = q = 2$)
- Rearrange each block into a pq X 1 vector.
- Form a data matrix A_1 of size pq X MN/pq by stacking each vector as its columns.
- Calculate the corresponding centered matrix ($\overline{A_1}$).
- Compute the scatter matrix T_1 of size pq X pq as $\overline{A_1}\,\overline{A_1}^T$.
- Diagonalize the scatter matrix by using eigen vector matrix U_1 ie., $U_1^T T_1 U_1 = S_1^2$, where S_1^2 = diag $(s_1(1)^2, s_1(2)^2, \ldots\ldots, s_1(pq)^2)$ contains the squares of the singular values of T_1 with $s_1(1)^2 \geq s_1(2)^2 \ldots\ldots\geq s_1(pq)^2$.
- Let matrix $\widehat{A_1} = U_1^T\,\overline{A_1}$ of size pq X MN/pq so that $\overline{A_1} = U_1 \widehat{A_1}$.

The top row of $\widehat{A_1}$ represented as $\widehat{A_1}(1,:)$ contains the largest eigen value, and hence may be considered as smooth or approximation component inherent in p X q blocks. Similarly, the remaining rows of $\widehat{A_1}$ corresponds to the remaining singular values in decreasing order and hence may be considered as detail components. Sub band images of size M/p X N/q can be formed by rearranging the elements in each row by filling in columns first. Sub band images of lena image at first level decomposition using MR-SVD is shown in Figure 1.

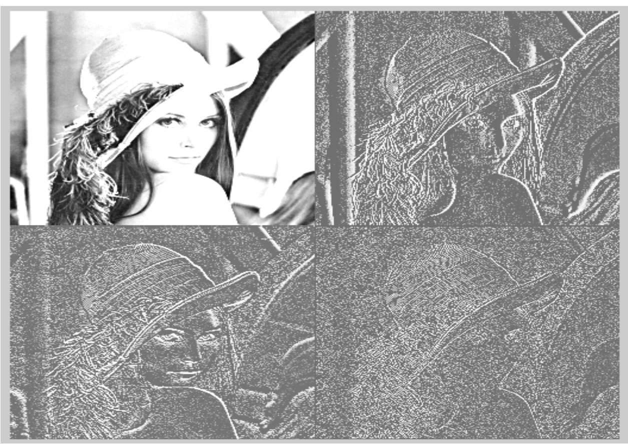

Figure1: First level decomposition of lena image using MR-SVD.

Proposed Method for Image Contrast Enhancement using MR-SVD

The intensity information of an image lies in the singular value matrix (Σ) [13], hence change in singular values results change in intensity of the image. The basic principle of image contrast enhancement using MR-SVD is adopted from DWT-SVD based image contrast enhancement technique. The existing algorithm of [7] is modified in order to implement with MR-SVD. The existing DWT–SVD based image contrast enhancement technique proposed in [7] is briefly given below.

DWT was applied on input low contrast image (A) and histogram equalized image ($\tilde{A}$) to obtain four sub band images. SVD was applied on LL sub band images of A and $\tilde{A}$ to obtain singular value matrices Σ_{LL_A} and $\Sigma_{LL_{\tilde{A}}}$ respectively. The correction coefficient was obtained by using Eqn. 2 [7]:

$$\xi = \frac{max(\Sigma_{LL_{\tilde{A}}})}{max(\Sigma_{LL_A})} \quad (2)$$

Where $\Sigma_{LL_{\tilde{A}}}$ is singular value matrix of LL sub band image of $\tilde{A}$ and Σ_{LL_A} is singular value matrix of LL sub band image of A.

The modified singular value matrix and new LL sub band image was obtained by using Eqns. 3 & 4 [7].

$$\overline{\Sigma_{LL_A}} = \xi \Sigma_{LL_A} \quad (3)$$

$$\overline{LL}_A = U_{LL_A} \overline{\Sigma_{LL_A}} V_{LL_A}^T \quad (4)$$

Inverse DWT was applied on four sub band images of A as show in Eqn. 5, to obtain enhanced image, A_E.

$$A_E = IDWT(\overline{LL}_A, LH_A, HL_A, HH_A) \quad (5)$$

The step by step procedure for proposed image contrast enhancement using MR-SVD is as follows:

Step 1: Let the image, A of size M x N such that M and N are dyadic.

Step 2: A is divided into 2 x 2 non overlapping blocks and each 2 x 2 block is converted to 4 x 1 vectors by stacking columns.

Step 3: A is reshaped to A_1 as 4 x MN/4 matrix by stacking each 4 x 1 vector of A as columns of A_1.

Step 4: By applying SVD on A_1, left singular vectors matrix, U of size 4 x 4 and singular value matrix, S of size 4 x MN/4, with four non zero singular values are obtained.

Step 5: A matrix $T = U^T A_1$ of size 4 x MN/4 is obtained.

Step 6: Four rows of T represent four sub bands. Each row is reshaped to obtain M/2 x N/2 sized sub band (LL_{A_1}, LH_{A_1}, HL_{A_1} and, HH_{A_1} sub bands respectively).

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Step 7: Image A is Histogram equalized and obtained equalized image, $\tilde{A}$.

Step 8: Steps 2 to 6 are applied on $\tilde{A}$ and obtained singular value matrix $\tilde{S}$ and sub band images $LL_{\widetilde{A_1}}$, $LH_{\widetilde{A_1}}$, $HL_{\widetilde{A_1}}$ and, $HH_{\widetilde{A_1}}$ of $\widetilde{A_1}$.

Step 9: Correction co-efficient $\xi = \frac{max(\tilde{S})}{max(S)}$ is computed.

Step 10: Modified LL sub band of A_1 is obtained by using equation, $\overline{LL_{A_1}} = \xi LL_{A_1}$

Step 11: Reshape $\overline{LL_{A_1}}$, LH_{A_1}, HL_{A_1}, HH_{A_1} sub bands of size M/2 x N/2 to 1 x MN/4 row vector.

Step 12: Form a 4 x MN/4 matrix, T_1 by stacking all four row vectors.

Step 13: A matrix $A_2 = UT_1$ is obtained; where A_2 is 4 x MN/4 matrix inherent in the 2x2 block format.

Step 14: Reshape A_2 to form contrast enhanced output image of size M x N.

Performance Evaluation Measures

Mean (μ) and Standard Deviation (σ) are commonly used metrics for brightness and contrast assessment respectively. Mean is a measure of average intensity of an image. The variance (σ^2) is a measure of spread of the intensities of an image about the mean in the image processing point of view. So variance is a useful measure of image contrast. Standard Deviation, which is square root of variance; provides values within the range of image intensity values and hence suitable for contrast measurement than variance [5]. For an image (A) of size M x N, the mean and standard deviation is obtained by using Eqns. 6 & 7 [5].

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

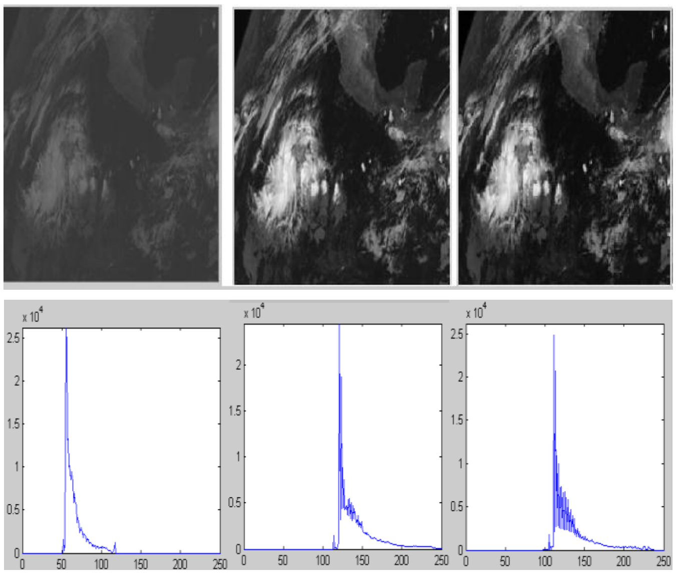
$$\sigma = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} (A_{i,j} - \mu)^2} \qquad (7)$$

In this paper, in addition to subjective analysis, the quantitative measures mean and standard deviation are used for objective analysis.

Results and Discussion

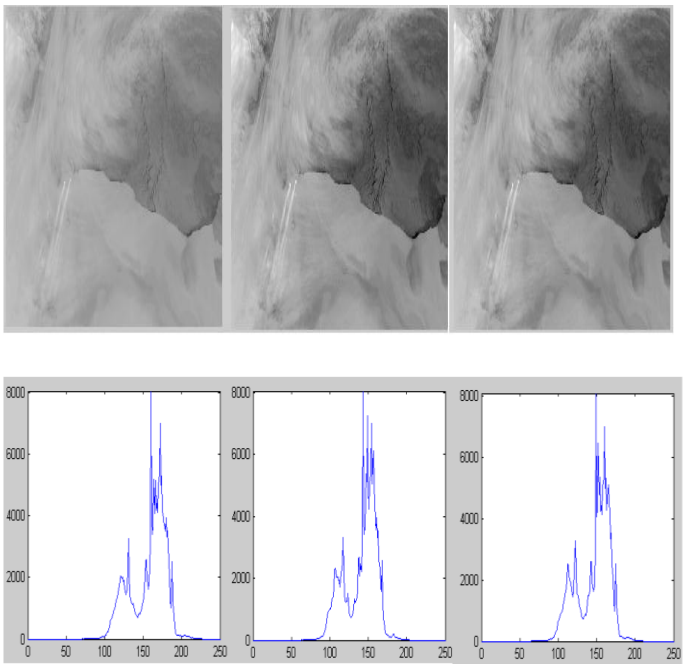
The input low contrast images are enhanced by using MR-SVD and compared with specified existing DWT and SVD based technique proposed in [7]. The original images in Figures 2 and 3 are of Antarctic Meteorological Research Center, obtained through internet [14].

Obtained output images with their corresponding histograms are shown in Figures 2 and 3. The quantitative results, mean and standard deviation are computed and tabulated in Table 1 for images shown in Figure 2. By observing the histogram plots in Figure 2 and Figure 3, it is evident that the shape of histograms did not changed.



(a) (b) (c)

Figure 2: Input low contrast image and Output images of different methods with their corresponding histograms. (a) Input low contrast image (b) DWT-SVD [7] (c) Proposed method with MR-SVD.



(a) (b) (c)

Figure 3: Input low contrast image and Output images of different methods with their corresponding histograms. (a) Input low contrast image (b) DWT-SVD [7] (c) Proposed method with MR-SVD.

Table 1: Mean and Standard Deviation values

Method	Images in Figure 2	
	Mean (μ)	Standard Deviation (σ)
Input	65.1961	12.7616
DWT-SVD [7]	117.1945	22.8152
Proposed Method using MR-SVD	144.7404	27.9772

CONCLUSION

In this paper, specified DWT – SVD based algorithm is modified in order to implement with signal adaptive transform MR-SVD. The proposed method using MR-SVD is compared with specified existing DWT – SVD based method. Mean and Standard Deviation are computed for quantitative comparison. Histogram plots and subjective results are also compared. From the results it is evident that the algorithm implemented with MR-SVD produces better results than to that of DWT – SVD in terms of standard deviation.

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