International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 4, Issue 4, April 2015

Comparative Study of Contrast Enhancement Techniques for Remote Sensing Images

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***Abstract*— Satellite images are used in many fields of research. Image enhancement is a technique to improve the contrast of the remote sensing data and to provide better representation of the remote image data. This paper proposes an enhancement method for satellite images which using the concept of dual tree complex wavelet transform , brightness level analysis and principal component analysis(PCA). Here the input image is decomposed into different wavelet subbands and the brightness level is computed in the LL subband using log average luminance. Based on the brightness level value LL subband decomposed into low, middle and high intensity layers. PCA analysis of the each decomposed layer is calculated and finally enhanced image is formed. The performance of this algorithm is compared using measurement of enhancement(EME),PSNR,MAE, and MSE. The experimental results show that the proposed algorithm enhances the overall contrast and visibility of local details better than existing techniques.**

***Index Terms*—contrast enhancement, dominant brightness level, Dual tree complex wavelet transform(DTCWT), principal component analysis(PCA), remote sensing images**

I. INTRODUCTION

Image enhancement is generally simplest and interesting areas of digital image processing. It is a method used to improve the overall quality of the degraded images and used to remove the irrelevant artifacts from the images. Several images like satellite images, medical images, aerial images etc face the problem of low contrast. In order to obtain the information from them we have to enhance these images with minimum error probability.

There are several methods are adopted for contrast enhancement of remote sensing images. Most of them are modifications of Histogram Equalization(HE) [1]. In brightness preserving Bi-Histogram Equalization (BBHE) [2] two separate histograms are taken from the same image and then equalized separately, where the first one is the histogram of intensities that are less than the mean intensity and the second one is the histogram of intensities that are greater than the mean intensity. In Dualistic Sub-image Histogram Equalization(DSIHE) [3] two separate histograms are created based on the median instead of mean. The Recursive Mean Separation Histogram Equalization (RMSHE) [4] enhances image by iterating BBHE technique. Recently, the gain controllable clipped histogram equalization (GC-CHE) [5] method performs clipped histogram equalization for preserving the brightness of an image. This also controls the gain of the reconstructed image. In Demirel's method of contrast enhancement the singular value decomposition matrix [6] -[7] was applied to the low level sub band. This method distorting the image details at low and high intensity regions. Although these methods increase the contrast of the image, these approaches usually leads to some undesired effects. The common problems caused by existing contrast enhancement methods are drifting brightness level variations, saturation problems , and false details. For this reason, enhancement algorithms for satellite images not only improve the contrast but also minimize pixel distortion in the low- and high-intensity region.

The proposed contrast enhancement algorithm first performs the DT-CWT to decompose the input image into a set of band-limited components. LL sub band has the illumination information and the log-average luminance of this band is computed for finding the dominant brightness level of the input image [8]–[10]. The LL sub band is decomposed into low, middle, and high intensity layers according to the dominant brightness level. The PCA is applied for the three intensity layers; finally enhanced image is reconstructed by using inverse DT-CWT.

II. PROPOSED APPROACH

Contrast enhancement of remote sensing images using DT-CWT and PCA is shown in Fig. 1

A. Dual Tree Complex Wavelet Transform

It is a modified version of DWT. The disadvantages of DWT are shift variant, directionally unselective, aliasing and oscillatory nature. Dual tree complex wavelet transform [11] overcomes all these problems. It is a complex valued extension of the standard wavelet.

This transform uses two real DWTs; the first DWT gives the real part of the transform while the second DWT gives the imaginary part. The two real wavelet transforms use two different sets of filters, with each satisfying the perfect reconstruction conditions. Two sets of filters are used in this technique. At each level of decomposition DT-CWT produces 6 directional sub bands oriented at different directions. Here four level decomposition is used and only LL sub band is taken ,because illumination information is contained only in LL.

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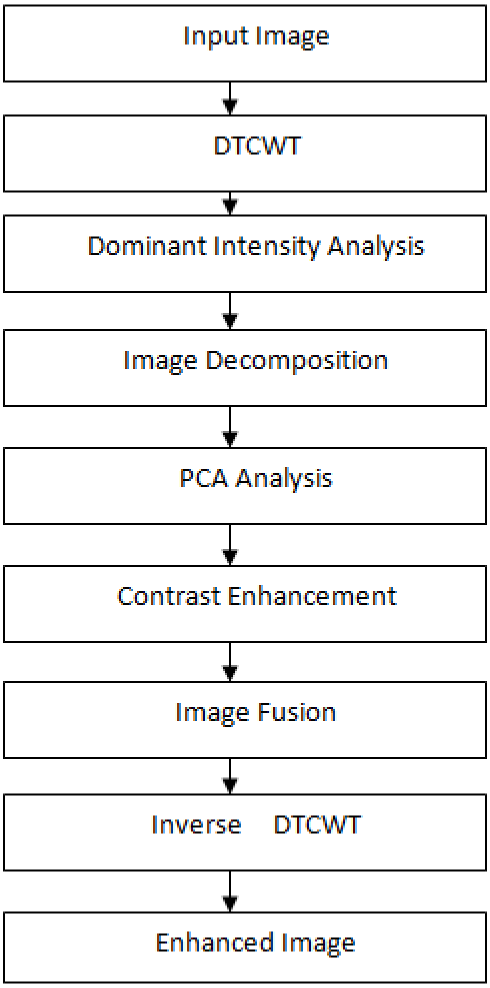

Fig.1. Block diagram of proposed method

B. *Dominant Intensity Analysis*

Contrast enhanced images may have intensity distortion and lose image details in some regions. For overcoming these problems, decompose the input image into multiple layers based on a single dominant brightness level. In this technique log average luminance value of LL sub band is taken and decomposes it into 3 different layers: low intensity layer, middle intensity layer, high intensity layer.

$$D(x,y) = exp\left(\frac{1}{N_L}\sum_{(x,y)\in S}\{Log\ L(x,y) + \varepsilon\}\right) \quad (1)$$

Where *S* represents a rectangular region encompassing *(x,y)*, *L(x,y)* the pixel intensity at *(x,y)* , '*P*' represents the total number of pixels in S, and ε represents a sufficiently small constant that prevents the log function from diverging to negative infinity. The low-intensity layer has the dominant brightness lower than the pre specified low bound. The high intensity layer has brightness level higher than the pre specified high bound, and the middle-intensity layer has the dominant brightness in between low and high bounds. Here 0.4 and 0.7 are taken for the low and high bounds, respectively.

C. *PCA Analysis*

Principle Component Analysis is a analytical tool used for analyzing data. It is widely used in pattern recognition, data compression and noise reduction. It takes large number of correlated variables and transform this data into a smaller number of uncorrelated variables, while retaining maximal amount of variation. It makes easier to operate the data and make predictions. In this method we can highlight similarities and differences.

III. Implementation Steps

Step 1: Read the input image
Step 2: Apply DT-CWT for that image
Step 3: Find out the brightness level in LL sub band using the Eqn (1)
Step 4: Based on the brightness level LL sub band decomposed into low, high and middle intensity layers
Step 5: Finding the PCA for all layers. Convert each layer into one dimensional vector

A = [x1, x2 ,x3 ,x4……..] (i=1 to m*n)

Where m = row;n=column;

Finding the mean value using this formula

$$K = \frac{1}{m*n}\sum_{i=1}^{m*n} \quad (2)$$

Step 6: Subtract the mean
Step 7: Calculate the covariance matrix.
Step 8: Calculate the eigenvectors and Eigen values of the Covariance matrix
Step 9: Finding Gaussian Factor with 5 x5 Mask

$$h = \frac{1}{sqrt(2*3.14)} e^{(x^2+y^2)} \quad (3)$$

Step 10: Finding maximum value of Gaussian coefficient (s1) And Eigen values (s)
Step 11: Multiply s1 with s this value will be the enhanced Factor
Step 12: Multiplying all sub bands with this enhanced factor
Step 14: Step 14: Three intensity transformed layers by using the PCA are fused to make the resulting contrast-enhanced image in the wavelet domain.
Step 15: Extract most significant two bits from the low, Middle, and high intensity layers for generating the Weighting map [14] and compute the sum of the two bit values in each layer. Select two weighting Maps that have two largest sums. values in each layer. Select two weighting Maps that have two largest sums.

The fused image' F ' is estimated as

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$$F = W_1 * c_l + (1 - W_1) * \{W_2 * c_m + (1 - W_2) * c_h \quad (4)$$

where W_1 represents the largest weighting map, W_2 represents the second largest weighting map, c_l is the contrast enhanced brightness in the low-intensity layer, c_m represents the contrast-enhanced brightness in the middle intensity layer, and c_h represents the contrast-enhanced brightness in the high-intensity layer. The fused LL sub band undergoes the IDWT together with the unprocessed other six sub bands to reconstruct the finally enhanced image.

IV. RESULTS AND DISCUSSIONS

In this section, simulation is carried out to evaluate the performance of the proposed method. Fig 2(a) shows original low-contrast image from Satellite Imaging Corporation [17]. In this paper, proposed method is compared with standard HE, RMSHE, GC-CHE, Demirel's,and Adaptive intensity transformation [11]-[12] method.

Histogram equalization method show under or oversaturation artifacts because it cannot maintain the average brightness level. Although RMSHE and GC-CHE methods can preserve the average brightness level, and better enhance overall image quality, they lost edge details in low- and high-intensity ranges. On the other hand, Demirel's method could not sufficiently enhance the low-intensity ranges because of the singular value constraint of the target image. And the adaptive intensity transformation fails to enhance all types of images. All these limitations are overcome in this proposed method.

Fig.2 (c) show the results of the proposed contrast enhancement method which using DTCWT and PCA. As per the block diagram Fig 2(b) shows the result of dominant intensity analysis. Based on the dominant intensity value image is decomposed into three layers low, middle and high intensity layers. Fig. 2(d)-(f) shows enhanced low, middle and high intensity layers. The overall image quality is significantly enhanced with preserving the average Brightness level and edge details in all intensity ranges .For performance evaluation, we used the measure of enhancement(EME) [16] which is computed as

$$EME = \frac{1}{K_1 K_2} \sum_{l=1}^{K_2} \sum_{K=1}^{K_1} \frac{I_{max}(k,l)}{I_{min}(k,l) + c} ln \frac{I_{max}(k,l)}{I_{min}(k,l)} \quad (5)$$

Where K_1, K_2 represents the total number of blocks in an image, $I_{max}(k,l)$ represents maximum value of the block, $I_{min}(k,l)$ represents minimum value of block and c represents a small constant to avoid dividing by zeros. Here 8x8 blocks are used and c =.0001

The parameters peak signal to noise ratio (PSNR), mean square error (MSR), mean absolute error (MAE) are also used for the performance evaluation. PSNR is the quality measurement between the original image and the reconstructed image which is calculated through the mean squared error (MSE). The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. MAE represents mean of the difference existing between two images. These parameters are calculated as follows: where $I(i,j)$ is the input image and $K(i,j)$ is the output image

$$MSE = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [I(i,j) - K(i,j)]^2 \quad (5)$$

$$MAE = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [I(i,j) - K(i,j)] \quad (6)$$

$$PSNR = 10log \frac{255^2}{MSE} \quad (7)$$

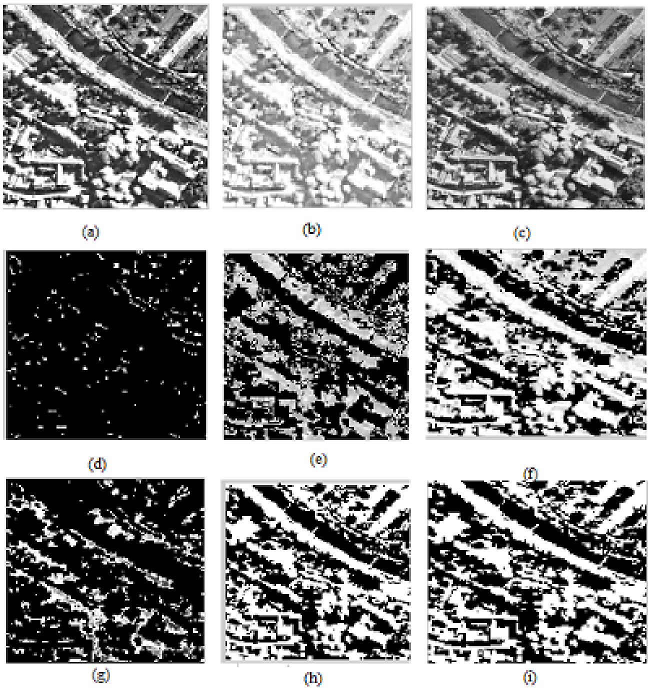

Fig. 2 (a) Original Image (b) Dominant Intensity Analysis (c) Enhanced Image (d) -(f) Decomposed low,middle,high intensity layers (g)-(i) Enhanced low,middle,high layers

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Fig. 3 Enhanced image by adaptive intensity method

Fig.4 Enhanced image by DTCWT & PCA

EME,PSNR,MSE,MAE values for different enhancement methods are listed in Table I.From the table of comparison it is clear that EME &PSNR values are higher for proposed method and MSE & MAE ARE lower for this method compared to other methods. Fig 5 shows the comparison of EME for different enhancement methods. Similarly Fig 6,Fig 7,Fig 8 shows the comparison study of MSE,MAE and PSNR. Proposed method outperforms than existing enhancement methods. This method is an efficient as compared to the other existing techniques which doesn't provides more enhancement over contrast and also the brightness can't be preserved, but the technique implemented here not only improves the contrast enhancement but also the intensity can be maintained.

TABLE 1: Comparison of results

METHODS	EME	MSE	PSNR	MAE
DTCWT & PCA	1.3265	22.43	20.14	26.13
ADAPTIVE INTENSITY	0.7313	24.65	20.32	24.23
SVD & DWT [6]	0.626	42.05	15.66	35.70
RMSHE[4]	0.680	64.31	10.12	54.06
BHE[2]	0.690	63.17	12.15	52.34
HE[1]	.689	42.17	15.54	37.92

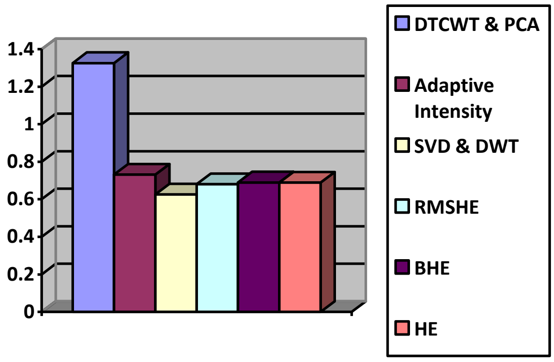

Fig. 5 Comparison of EME of different enhancement methods

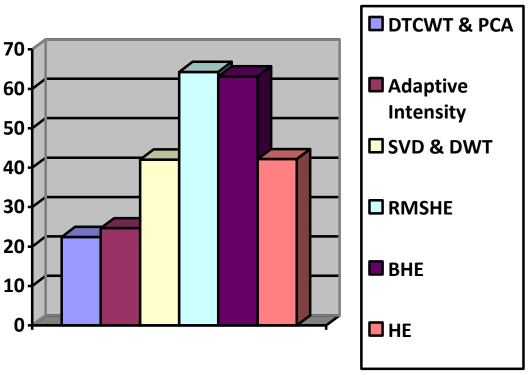

Fig. 6 Comparison of MSE of different enhancement methods

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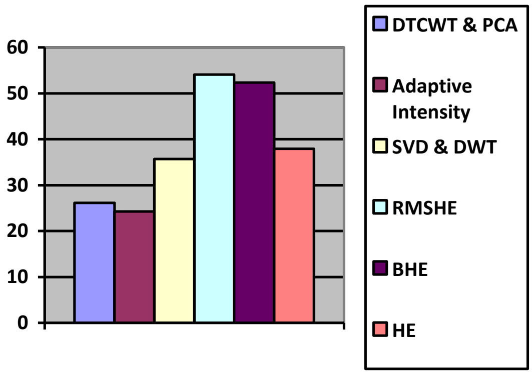

Fig. 7 Comparison of MAE of different enhancement methods

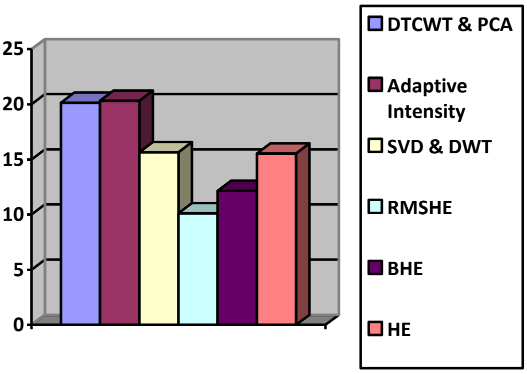

Fig.8 Comparison of PSNR of different enhancement methods

V. CONCLUSION

Here presented a novel contrast enhancement method for remote sensing images using DT-CWT ,brightness level analysis and PCA. The proposed algorithm decomposes the input image into wavelet sub bands and decomposes the LL sub band into low ,middle , and high intensity layers by analyzing the log average luminance of the corresponding layer. The PCA analysis is applied for all these layers and all the contrast enhanced layers are fused with an appropriate smoothing, and the processed LL band undergoes the IDT-CWT together with unprocessed other sub bands. The proposed algorithm can effectively enhance the overall quality and visibility of local details better than existing methods including RMSHE,GC-CHE, Demirep's and adaptive intensity methods. Experimental results demonstrate that the proposed algorithm can enhance the low-contrast satellite images and is suitable for various imaging applications.

ACKNOWLEDGMENT

First and foremost, praises and thanks to the God, the Almighty, for His showers of blessings throughout my project work to complete it successfully. First of all I would like to acknowledge with much appreciation the Pivotal role of my guide , Prof. Shine P. James, who gave his full support to complete my work. This work would not have been possible without his guidance, support and encouragement. Under his guidance I successfully overcame many difficulties and learned a lot.

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