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Satellite Image Contrast Enhancement using Lifting Wavelet Transform and Singular Value Decomposition

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***Abstract*— In this paper, Lifting Wavelet Transform (LWT) and Singular Value Decomposition based technique for satellite contrast enhancement has been proposed. In this procedure utilizing LWT the information picture disintegrates into four recurrence sub-groups and the solitary esteem lattice of the low-low sub-band picture is anticipated picture and after that the improved quality picture is revamped by utilizing opposite LWT. This methodology is then compared with local histogram equalization and standard general histogram equalization which are techniques of conventional image equalization, additionally the best in class strategies, for example, brilliance saving unique histogram evening out and solitary esteem balance. The experimental outcomes illustrates the excellence of proposed method extending conventional and state of the art techniques.**

Keywords*— Lifting wavelet transform, image equalization, satellite image contrast enhancement.

I. INTRODUCTION

In many applications alike geographical information systems geosciences studies, and astronomy satellite images are required and used. In satellite images their contrast is referred as utmost significant quality factor. Several of the images captured by satellite persist with low contrast, blur impact and noisy data in it. In image processing contrast enhancement of the captured satellite image is oftentimes stated as the most important issue. The contrast is formed by variance in luminance reflected from two contiguous surface. The visual system of human is extra sensitive to the contrast than consummate luminance. So in visual acuity, the variance in the brightness and color of an object with other objects determines the contrast.

There is a chances of information loss of the extremely and unvaryingly concentrated area , if the contrast of captured satellite image is exceedingly concentrated on a precise range. The issue is to augment the contrast of an image in form to represent all the information in the input image. The quite a few techniques are there to beaten up this problem [1]-[4], just as local histogram equalization (LHE) and general histogram equalization(GHE). The outcomes can also be calculated with two techniques of state-of-art named as singular value equalization (SVE) [5] and brightness preserving dynamic histogram equalization (BPDHE) [6].

In number of image processing applications, for contrast enhancement the GHE technique is referred as one of the uncomplicated and utmost impressive fundamental [7], which pursuit to produce an outcome histogram that is invariable[8]. The information rested on the histogram or probability distribution function (PDF) of the image will be lost is deprivation of GHE. The PDF of face images might be used for face recognition is explained by Demirel and Anbarjafari[9], therefore conserving the form of the PDF of an image is of vigorous important. To conserve the conventional patterning of PDF of the image there are few techniques which can used BPDHE or SVE. From dynamic histogram specification [10] BPDHE is gained that helps to produces the described histogram dynamically from the input image.

The image equalization (SVE) method based on singular-value [6], [9] is grounded on standardizing the singular value matrix attained by singular value decomposition (SVD). The image's SVD can be composed as a matrix, which is inscribed as follows:

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

Here V_A and U_A are orthogonal square matrices recognized as hanger and aligner, correspondingly, and the $\sum_A$ matrix encompasses the assort singular values on its main diagonal. The main inkling of using SVD for image equalization derives from this fact that ΣA holds the intensity information of a given image [11].

In previous slog [6], [9], SVD was avail to deal with an illumination issue. That method customs the proportion of the biggest singular value of the created normalized matrix, with mean zero and variance of one, done with a normalized image which can be computed conferring to

$$\xi = \frac{\max(\Sigma_{N(\mu=0,var=1)})}{\max(\Sigma_A)} \qquad (2)$$

Here $\Sigma_{N(\mu=0,var=1)}$ is the singular value matrix of the synthetic intensity matrix. This coefficient is used to rebuilt an equalized image using

$$\Xi_{\text{equalized } A} = U_A(\xi \Sigma_A) V_A^T \qquad (3)$$

Here $\Xi_{\text{equalized } A}$ is depicting the equalized image A. This work is removing the illumination issue.

At the present time, in image processing wavelets are frequently used, which is avail for denoising [12], face recognition [13], satellite image super-resolution [14], feature extraction[15], and compression [16]. The disintegration of images into distinct frequency bands consent the desolation of frequency fundamental popularized by "extrinsic factors" within assertive sub-bands [17]. This procedure outcomes in desolating cramped changes of an image in high frequency sub-band images. Thus, Lifting Wavelet Transform (LWT) is convenient technique to be worth for scheming a pose invariant face recognition system. The 2D wavelet decomposition of an image is perform by applying 1D wavelet transform first on the rows of image and then results are decomposes along the columns. The image is divided within four sub-band figures as high-high(HH), high-low(HL),low-low(LL), low-high(LH),. The frequency elements of input image is covered by the frequency elements of those sub-band images. The filter bank shows in Fig.1.

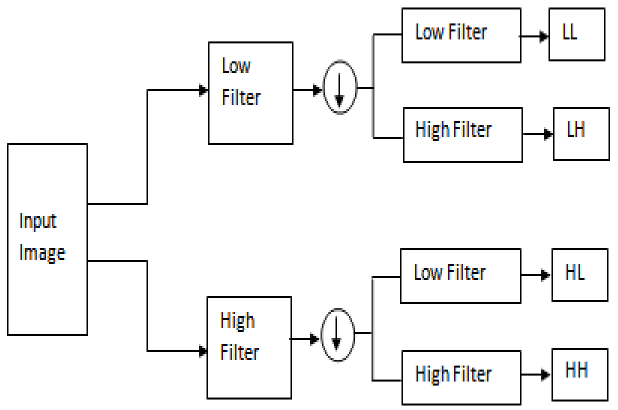

Fig.1 Filter Bank.

In this a recent technique for satellite equalization is proposed which is an extent of SVE, and the technique is situated at singular value decomposition of an sub-band i.e low-low(LL) sub-band image which is gained by LWT. LWT helps to detached the low contrast input satellite image into distinct frequency sub-band, Where the low-low(LL) sub-band focusses the illumination information. Because of this only low-low(LL) sub-band undergo through the SVE procedure, which conserves the high-frequency elements (i.e., edges).Hence, afterward inverse LWT (ILWT), the conclusion image will be shriller with respectable contrast. In this work, the anticipated process has been related with the conventional GHE technique in addition to LHE and BPDHE and SVE. The outcomes specify the dominance of the anticipated process over the aforementioned methods.

II. PROPOSED METHODOLOGY

A. LWT-Based Contrast Enhancement

Previously it was mentioned that the image's contrast is an crucial characteristic in satellite image, which makes the contrast enhancement of satellite image to be of vital importance as the abnormal that is excess contrast of an image will directly affect the information of image i.e. there is high chances of data misfortune. In this paper, LWT has been used in order to sustain the high frequency element of the image. LWT segregate the input image within distinct sub-band frequency images such as HH,HL,LL,LH. The output image will not be improved only with contrast but also will be sharped after reconstructing the image by applying ILWT.

There are mainly two parts of the determined method, first is the SVD usage. The singular value matrix which is obtained by SVD holds the illumination information. That's why the small change in singular value will directly affects the illumination of the image. The second part is LWT. The illumination information is encapsulated in the LL sub-band image. The edges are concerted in other sub-band i.e. LL,LH,HL,HH. Implementing the enhancement of illuminance in the Low-Low sub-band and the segregation of high frequency sub-band only will defend the information from degradation. Afterwards rebuilding the final image via ILWT, the consequential image will not only be improved with respect to illumination but also will be shriller.

The rough procedure of the defined technique is as follows:

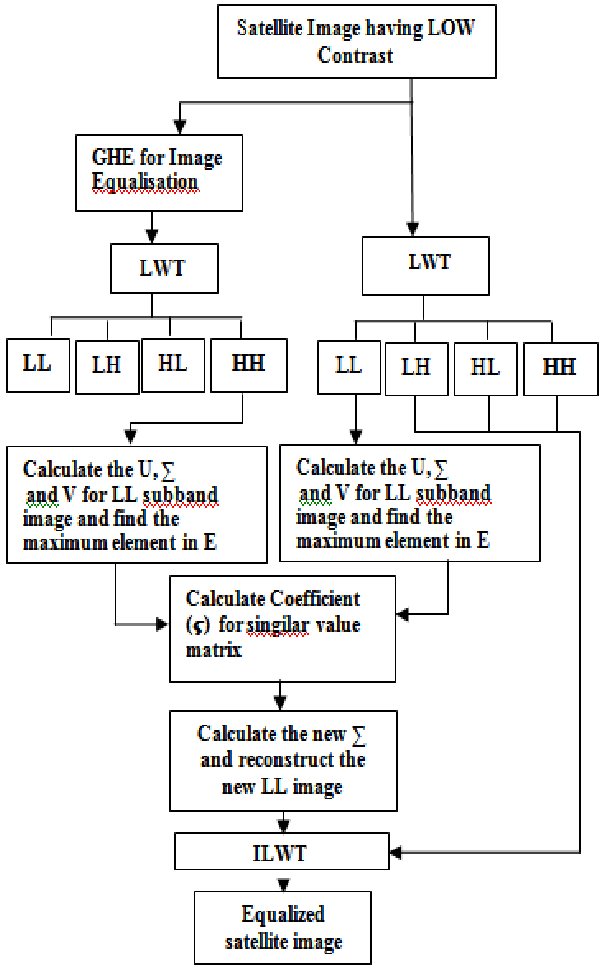

Fig. 2 Steps of Equalization Technique

Step 1 : First of all with the help of GHE the input image A will be processed to generate new image $\hat{A}$.

Step 2: After that both images are transformed by LWT into four sub-band images.

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Step 3: By using mentioned formula the correction coefficient for singular value matrix is calculated.

$$\zeta = \frac{\max(\sum LL_{\hat{A}})}{\max(\sum LL_{\hat{A}})} \qquad (4)$$

Here. $\sum_{LL\,A`}$ = LL singular value matrix of output of GHE.

$\sum_{LL\,A}$ = LL singular matrix of input image.

Step 4 : The new LL image is composed by

$$\bar{\sum}_{LLA} = \zeta \sum_{LLA}$$

$$\overline{LL}_{A} = U_{LLA} \bar{\sum}_{LLA} V_{LLA} \qquad (5)$$

Step 5: Now, to generate final equalized image $\hat{A}$ the $\overline{LL}_A$, LH_A, HL_A, and HH_A sub-band images are recombined by applying ILWT.

$$\bar{A} = \text{ILWT}(\overline{LL}_A, LH_A, HL_A, HH_A) \qquad (6)$$

In this letter, the db.9/7 wavelet function is used as the main function of LWT.

B. Lifting Wavelet Transform Process

The wavelet analysis is new algorithm which established in recent years. The lifting wavelet transformation's basic arithmetic is through a female wavelet / lazy wavelet to construct new better image. It has three different steps as follows: Split , Predict and Update.

1) Split : Decompose input signal into two subset that do not intersects mutually S_{j-1} and D_{j-1} ,

$$F(S_j) = (S_{j-1}, D_{j-1}).$$

2) Predict : In the view of relevant data , available S_{j-1} precognise D_{j-1} . So be premitted to use one uncreative precognised operatore P , fulfilled $d_{j-1} = P(S_{j-1})$, like this to be allowed to use the child data set Sj . If replaces D_{j-1} and the precognised subset $P(S_{j-1})$, then this distinction revert both approach degree. If precognised is fair then the difference data set involve information is lower than the information of premitive subset D_{j-1}. Precognised processing is as folllows:

$$D_{j-1} = D_{j-1} - P(S_{j-1})$$

3) Update : As disintegrate the subset , original set it looses some characteristtics , produce the subset data and original set data that have same characteristics likewise has a superior sub data set S_{j-1} over operator U, compose it to preserve original dataset S_j some characteristics. The definition of S_{j-1} is as follows :

$$S_{j-1} = S_{j-1} + U(D_{j-1})$$

The recreating data build up formula is as same as the disintegrating formula, Only the change in computation order is needed:

$$S_{j-1} = S_{j-1} - U(D_{j-1})$$
$$D_{j-1} = D_{j-1} + P(S_{j-1})$$
$$S_j = \text{Merge}(S_{j-1}, D_{j-1})$$

Merge is the consolidation that uses the splits subset S_{j-1} and D_{j-1} to recreate, redevelop initial signal.

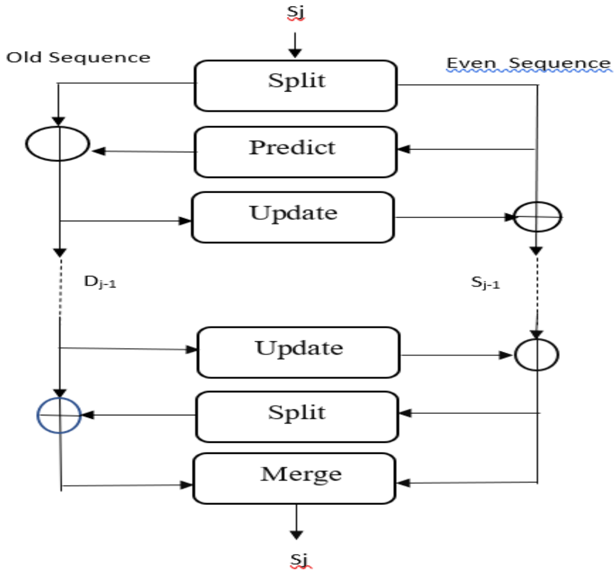


Fig. 3 LWT Algorithm Diagram

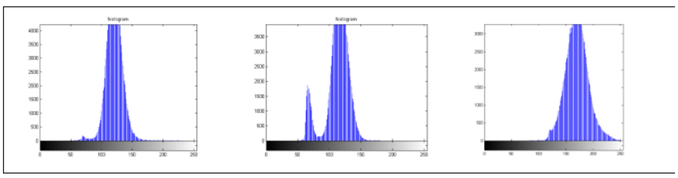
In the succeeding sector, the experimental outcomes and the evaluation of the aforementioned conventional and state-of-the-art techniques are deliberated.

III. RESULT AND DISCUSSION

Fig. 4.: (a) (b) (c) presents the satellite images having low contrast. The histogram of these images are shown in [Figs. 4.1: (a1) (b1) (c1)] , These images are standardized by using GHE shows in [Figs. 4.2:(a2) (b2) (c2)],the proposed equalization technique LWT-SVD [Figs. 4.3 (a3) (b3) (c3)]. Proposed algorithm is giving favorable value of mean and minimal standard deviation, same as MSE and PSNR are also illustrates the comparatively values i.e maximum and minimum for all the 3 sample satellite images, and also it is tested to more satellite images which are having low contrast. The performance in terms of visual aspect is also better than the GHE, DCT-SVD and DWT-SVD. The satellite images used is of different sizes and different contrast level.

(a) (b) (c)

Fig 4.: Input low contrast image (a) - (c)



(a1) (b1) (c1)

Fig 4.1.: Histogram of input image (a1) - (c1)

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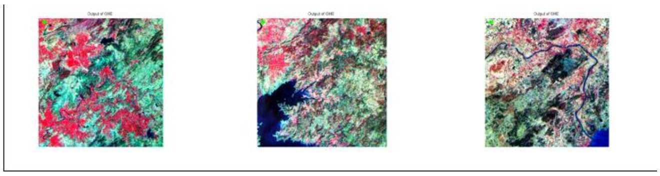
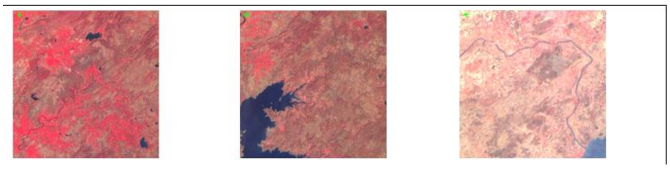


(a2) (b2) (c2)

Fig 4.2: Output of GHE (a2) - (c2)



(a3) (b3) (c3)

Fig 4.3: Enhanced images by LWT-SVD (a3) - (d3)

Experiments have been completed on over 100 haphazardly certain images from numerous sources which confirmed the approximate outcome. In order to backing the approximate inferences on the dominance of the anticipated technique, a measurable analysis is essential. However, when the crushed certainty that signifies the original image is mislaid, a measurable error analysis on the enhanced image is not possible.

IV. CONCLUSION

In this paper, for satellite image new technique for contrast enhancement is proposed based on LWT and SVD. In this technique the input image is decomposes into LWT four sub-band (LL,LH,HL,HH) and upgradation of singular value matrix of LL sub-band is done. After that reconstruction of an image is done by applying ILWT. The proposed technique is differentiated with LHE, GHE, SVE and BPDHE techniques. The final result shows the supremacy over the all previously defined techniques.

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