Comparative Analysis of Various Enhancement Methods for Satellite Images

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***Abstract*—In this paper, a comparison of the satellite image contrast enhancement techniques is being carried out. Satellite images are being used in many fields of research. One of the major issues of these types of images is their resolution. Here discrete wavelet transform (DWT) is used as a base and two techniques for enhancing the images are compared. The DWT technique decomposes the input image into the four frequency subbands and in the first method it estimates the singular value matrix of the low–low subband image, and, then, it reconstructs the enhanced image by applying inverse DWT. The second technique is based on the interpolation of the high-frequency subbands obtained by discrete wavelet transform (DWT) and the input image. The high-frequency subband images and the input low-resolution image are interpolated and then combined together to generate a new resolution-enhanced image by using the inverse DWT technique. The experimental results show the comparison between the two methods which help us to make a choice for better satellite image enhancement technique.**

***Index Terms*— Discrete wavelet transform, image equalization, interpolation, satellite image resolution enhancement.**

I. INTRODUCTION

Satellite images are used in many applications such as astronomy, study of geosciences and geographical systems. In the satellite images contrast plays a vital role in judging the quality of an image. The difference in the luminance reflected from two adjacent surfaces gives contrast whereas in the case of visual perception it is determined by the difference in the colour and brightness of an object with other objects.

The contrast of an image must be optimized in order to preserve the information when it is highly concentrated on a specific range. In order to overcome the above problem techniques such as general histogram equalization and local histogram equalization have been proposed in the literature [1]–[4].

In image processing interpolation technique is used to increase the number of pixels in an image. Interpolation technique has been widely used in many image processing applications, such as the facial reconstruction [5], the multiple description coding [6], and the image resolution enhancement [7]–[9]. Image enhancement using interpolation technique has been widely used in literature for providing a good quality of images. There are three popular interpolation techniques found in literature namely the nearest neighbour, the bilinear and the bicubic. Bicubic interpolation is more sophisticated than the other two techniques and produces smoother edges compared to the other two techniques.

Wavelets play a significant role in many image processing applications. The 2-D wavelet transform results in four decomposed subband images referred to as low-low (LL), low-high (LH), high-low (HL), and high-high (HH) bands covering the full frequency spectrum of the original image.

In this work, the results are compared with two state-of-the-art techniques. In the first method the singular value matrix of the low–low subband image is estimated and then the enhanced image is reconstructed by applying inverse DWT. The second technique is based on the interpolation of the high-frequency subband obtained by applying discrete wavelet transform (DWT) to the input image. The high-frequency subband image and the input low-resolution image are then interpolated and combined to generate a new resolution-enhanced image by using inverse DWT.

II. SATELLITE IMAGE ENHANCEMENT BASED ON SVD TECHNIQUE

The singular-value-based image equalization (SVE) technique as shown in [10, 11] is used for equalizing the singular matrix which is obtained by using decomposition of singular value matrix. The decomposition of an image, usually obtained in the form matrix is shown below:

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

where U_A and V_A are the orthogonal matrices and the Σ_A is a matrix that contains singular values sorted along its diagonal element. The purpose of using the decomposed image is for the fact that it gives the intensity information of a given image [12].

In the literature work ([10], [11]), the decomposition method was used to overcome the illumination problem. The above method uses the ratio of the largest singular value matrix which is normalized and has mean of zero and variance of one, over a normalized input image which is obtained according to the equation shown:

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

where $\Sigma_{N(\mu=0,\mathrm{var}=1)}$ is the normalized singular value matrix and the equalized image can be obtained using the equation shown below:

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

where $\Xi_{equalized_A}$ represents the equalized image *A* and the task is to eliminate the illumination problem.

A comparative method is introduced for the satellite image enhancement which is an extension of the SVE method. DWT is used to separate the input low contrast image into different frequency subbands, where the LL subband concentrates on the illumination information. Thus the LL subband goes through the SVE process, which preserves the high-frequency components (i.e., edges). Hence, after inverse DWT (IDWT) the resultant image will be sharper with good contrast.

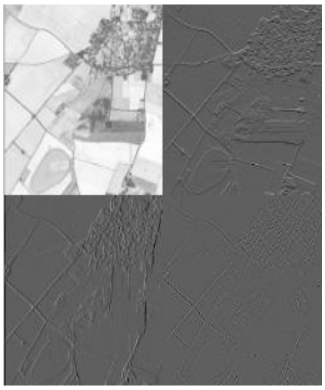

Figure.1 LL, LH, HL, and HH subbands of a satellite image are obtained by using DWT.

There are two significant parts in the proposed technique, firstly using the SVD technique and then applying the DWT method. LL band gives the information of illumination and the edges are concentrated in the other subbands (i.e., LH, HL and HH). Thus the high-frequency subbands are separated to protect from image degradation and the enhancement is applied only to the LL subband. Hence the final reconstructed image will be much enhanced and sharper compared to the original image.

The general histogram equalization method is used to process the input image *A* and the processed image is designated as $\bar{A}$. The correction factor for the singular value matrix for all the four subbands obtained from DWT method is calculated as shown below:

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

where Σ_{LL_A} is the singular matrix of the Low-Low band for an input image and $\Sigma_{LL_{\hat{A}}}$ is the singular matrix of the Low-Low band for the output image using the proposed method. Finally the new Low-Low band image is obtained by

$$\bar{\Sigma}_{LL_A} = \zeta \Sigma_{LL_A}$$
$$\overline{LL}_A = U_{LL_A} \Sigma_{LL_A} V_{LL_A} \qquad (5)$$

Now, the $\overline{LL}_A$, LH_A, HL_A, and HH_A subband images of the original image are recombined by applying IDWT to generate the resultant equalized image $\bar{A}$

$$\bar{A} = IDWT(\overline{LL}_A, LH_A, HL_A, HH_A) \quad (6)$$

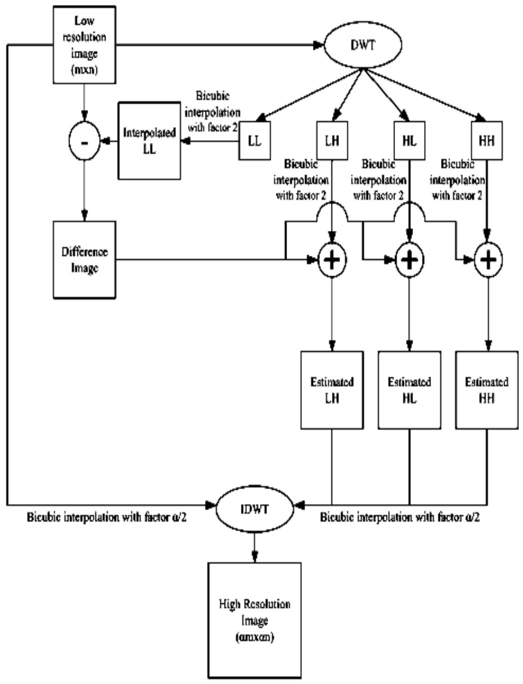

Figure.2 Block diagram of the proposed resolution enhancement algorithm

III. SATELLITE IMAGE ENHANCEMENT BASED ON DWT-BASED RESOLUTION ENHANCEMENT

In satellite imaging, resolution proves out to be an important feature and enhancement of the same becomes very important for the images. Enhancing the resolution of the input satellite images will affect the performance of the system. The high frequency components usually get affected or lost when interpolation technique is applied for enhancing the resolution of the satellite image. Preserving the edges becomes very important to increase the quality of an image. In this technique, the frequencies in high band are usually preserved by employing DWT [13] to the image. DWT method separates the image into four subband images namely LL, LH, HL, and HH. High-frequency subband contains the high frequency component of the input image. The interpolation method can be applied to these four subband images as shown.

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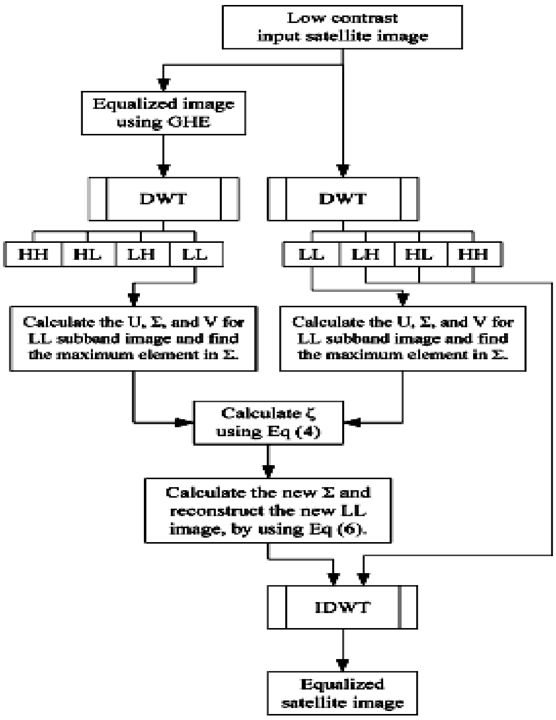


Figure.3 Algorithm for proposed equalization technique

A low-resolution image is obtained from the high-resolution image as in [14], [15], and [13] by making use of a low pass filter. The low resolution image (LL band) obtained without quantization is used as the input for the resolution enhancement process. Images with low frequencies contain less information as compared to the original image, so they are usually passed through the interpolation process and the resultant image is taken as input. Thus the input image is first interpolated with half of the interpolation factor $\alpha/2$ and then it is used to interpolate the high-frequency subbands as shown in Fig.2. To preserve the edges perfectly an intermediate stage is introduced in the high frequency band and a sharper enhanced image is obtained.

The low-resolution input image and the interpolated LL image will be highly correlated and the difference between them will give high-frequencies. Then an intermediate process is used to correct the estimated high-frequency components. The estimation is then carried out by interpolating the high-frequency subbands by a factor 2 and the obtained difference image is included into the high-frequency images. Finally the obtained image is interpolated by a factor $\alpha/2$ so that the process reaches the required size for IDWT process. The intermediate process will give significantly sharper and clearer enhanced image.

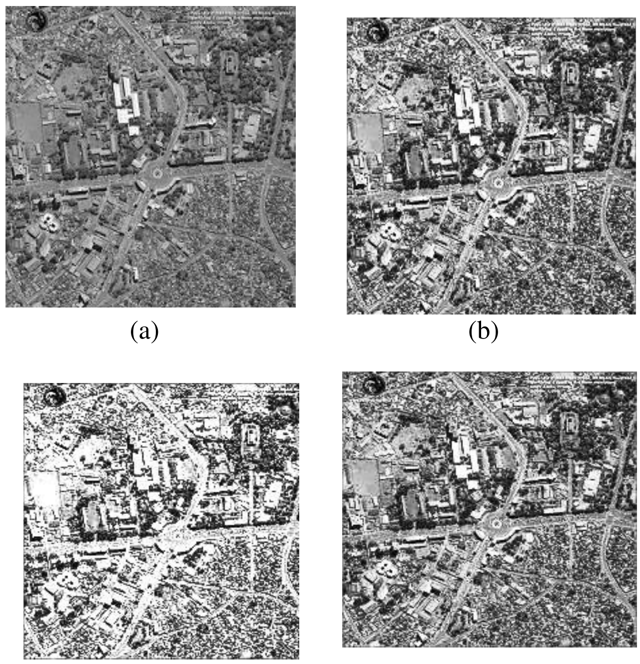
IV SIMULATION RESULTS

Figs. 1(a), 2(a) show the low-contrast images taken from aerospace and geosciences resources. These images have been equalized by using GHE [Figs. 1(b), 2(b)], SVE i.e. the proposed technique [Figs. 1(c), 2(c)] and the Enhanced Image [Figs. 1(d), 2(d)]. The proposed equalization method proves out to be better in terms of quality than general histogram equalization method. It produces sharper and brighter edges.

The technique using Bicubic Interpolation is tested on several satellite images. When this technique is applied on a low-resolution satellite image, the enhanced images are shown in the figures below.

It is evident from the obtained figures that the proposed technique produces sharper edges than the other techniques. Fig.7 shows (a) Low-resolution image (b) high-resolution image obtained by using bicubic interpolation on LL Subband, (c) interpolation on HL Subband, (d) Interpolation on HL Subband, (e) Interpolation on HH Subband.

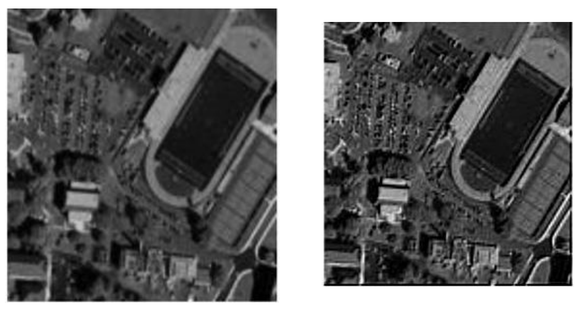
Figs. 4, 5 and 6 show the effectiveness of the proposed SVD and DWT based Resolution Enhancement methods over the standard GHE, the Bicubic interpolation and the Bilinear Interpolation based satellite image resolution enhancement techniques. Different benchmark images with different features are used for the comparison.



(a) (b)

(c) (d)

Figure. 5. (a) Original low-contrast image. Equalized image by using (b) GHE, (c) Proposed technique (d) Enhanced Image



(a) (b)

Figure.6 Low Resolution (a) Input Image (b) High Resolution Output Image, High Resolution Image

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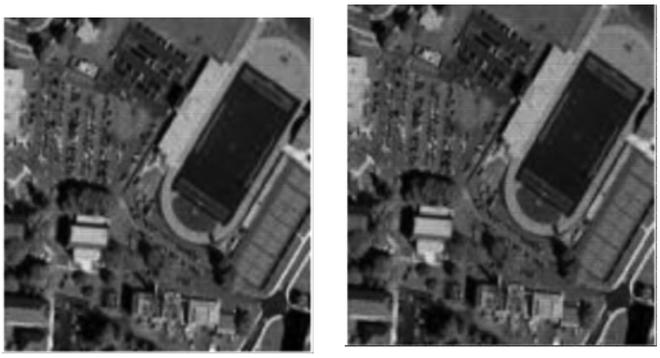
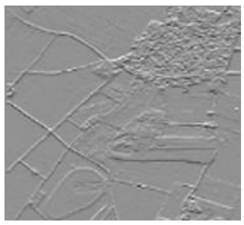


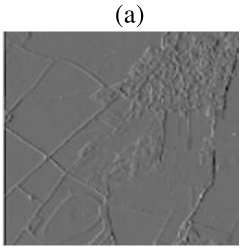
(c) (d)

Figure.6 Low Resolution, (c) Bicubic Method (d) Bilinear Method

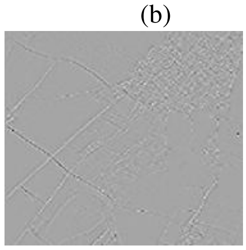
(a)



(b)



(c)



(d)

(e)

Figure 7 (a) Low-resolution image (b) high-resolution image obtained by using bicubic interpolation on LL Subband, (c) interpolation on HL Subband, (d) Interpolation on HL Subband, (e) Interpolation on HH Subband.

CONCLUSIONS

In this work, a comparative analysis on satellite image contrast enhancement techniques is shown based on the DWT and the SVD methods. In the former, making use of DWT method, singular value matrix of the LL subband is obtained and then updated, and finally the enhanced image is reconstructed by using IDWT. The technique is also compared with the GHE method. On the contrary, the later technique is based on the interpolation of the high-frequency subband images obtained by DWT of the input image and the visual comparison is seen through the simulation results obtained.

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