Wavelet Based Design and Simulation of Brightness, Contrast and Resolution Enhancement of Satellite Images

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Abstract

The resolution, brightness and contrast enhancement technique for satellite image based on the discrete wavelet transform (DWT) and singular value decomposition (SVD) and Histogram Equalisation has been proposed. Satellite images are used in different fields for various applications such as in the field of regional planning, intelligence, astronomy, meteorology, agriculture, forestry, landscape, biodiversity, education, warfare, conservation, and geosciences studies and geographical information systems. All the important quality factors in an image come from its resolution. The resolution of satellite image is enhanced using the DWT technique. The technique decomposes the input image into the four frequency sub- bands and estimates the singular value matrix of the low–low sub band image which is then reconstructed to the enhanced image by applying inverse DWT. This technique estimates the singular value matrix of the low–low sub band of histogram equalized image and then normalize both singular value matrices to obtain a brightness enhanced image. The resolution and brightness enhanced image is enhanced in contrast with the Global Mean and Variance technique. This technique is compared with the conventional image equalization techniques such as standard general histogram equalization and local histogram equalization, and state-of--art technique such as brightness preserving dynamic histogram equalization and singular value equalization. The experimental result obtained shows the superiority of the proposed method over conventional techniques.

Keywords— ***Bi-cubic interpolation, discrete wavelet transform (DWT), mean square error (MSE), peak signal to noise ratio (PSNR), singular value decomposition (SVD), global mean and variance, satellite image resolution enhancement, satellite image brightness enhancement, satellite image contrast enhancement.***

1. Introduction

Image Enhancement is the process of modifying the image so that it becomes suitable for various applications. There are different approaches for image enhancement such as the frequency domain and the spatial domain methods. In the frequency domain method the Fourier transform of the image is enhanced whereas in the spatial domain the pixels of the image are directly modified. The combination of these methods is being used in image enhancements. Any type enhancement of image is always recognized and judged by the visual perception of the viewer.

Resolution is one of the major concerns in image and video processing applications such as feature extraction, video resolution enhancement and satellite image resolution enhancement. In the DWT process for Image Enhancement, we use Interpolations as well as Lifting Scheme for increasing the number of pixels in the image.Interpolation is a method that is used to increase the number of pixels in a digital image.

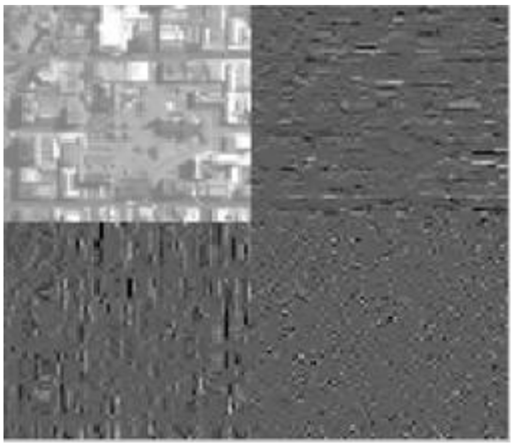

Figure 1: DWT Process

Interpolation is being widely used in image processing applications, such as multiple description coding, facial reconstruction and image resolution enhancement. The interpolation technique for image resolution enhancement has been used for a long time and this interpolation technique has been developed to increase the quality of the task.

Wavelets also play a significant role in image processing applications. The 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform (DWT) to the rows of the image first, and then the results are decomposed with the columns. This operation results in four decomposed sub-band images referred to low-low (LL), low-high (LH), high-low (HL), and high-high (HH).The frequency components of these sub-bands cover the full frequency spectrum of the original image.

In this paper, we proposed a resolution-enhancement technique by using interpolated DWT high-frequency sub-band images and the input low-resolution image. Inverse DWT (IDWT) is applied to combine all these images to generate the final resolution-enhanced image. To achieve a sharper image, we used an intermediate stage for estimating the high frequency sub-bands by utilizing the difference image obtained from subtracting the input image and its interpolated LL sub-band .We also proposed a brightness enhancement technique using SVD method on low frequency sub-band image of both input and histogram equalised images. The proposed technique is compared with standard interpolation techniques, wavelet zero padding (WZP), wherein the unknown coefficients in high-frequency sub-bands are replaced with zeros, and state-of-art techniques, such as WZP and cycle spinning (CS), and previously introduced complex wavelet transform (CWT)-based image resolution enhancement. Here we also proposed a contrast enhancement to image output obtained after the resolution and brightness enhancement using the Global Mean and Variance technique. This proposed technique is compared with the Local mean and Variance technique where in a better contrast enhancement is obtained.

The paper is organized as follows. Section II gives an overview on the resolution enhancement techniques used for comparison purposes. Section III introduces the proposed wavelet based resolution, brightness and contrast enhancement technique. Section IV discusses the qualitative and quantitative results of the proposed method with the conventional and state-of-art resolution enhancement techniques. Conclusion is given in the final section.

2. Existing Methods

There are several methods which are been used for satellite image resolution enhancement. In this paper, we have used two techniques for comparison purposes. The first one is WZP and CS [18], and the second one is the previously introduced CWT-based image resolution enhancement [3].

A. CS Based Image Resolution Enhancement

This method uses the CS methodology in the wavelet domain [15]. The algorithm consists of two main steps which are as follows:

1) An initial approximation is generated to the unknown high resolution image using wavelet domain zero padding (WZP).

2) The cycle-spinning methodology is used to operate the following tasks:

a) From the estimated high resolution image obtained in part (1) by spatial shifting , wavelet transforming, and discarding the high frequency sub bands a number of low resolution images are generated.

b) The WZP processing is applied to all these low resolution images yielding N high resolution images.

c) This intermediated high resolution images are re-aligned and averaged to get the final high resolution re-constructed image.

B. CWT-Based Image Resolution Enhancement

In this technique, a dual-tree CWT (DT-CWT) technique is used to decompose an input image into different sub band images. DT-CWT is used to decompose an input low-resolution image into different sub bands. Then this high-frequency sub band images and the input image are interpolated, followed by combining all these images to generate a new high-resolution image by using inverse DT-CWT. The resolution enhancement is achieved by using directional selectivity provided by the CWT, where the high-frequency sub bands in the six different directions contribute to the sharpness of the high-frequency details which includes edges.

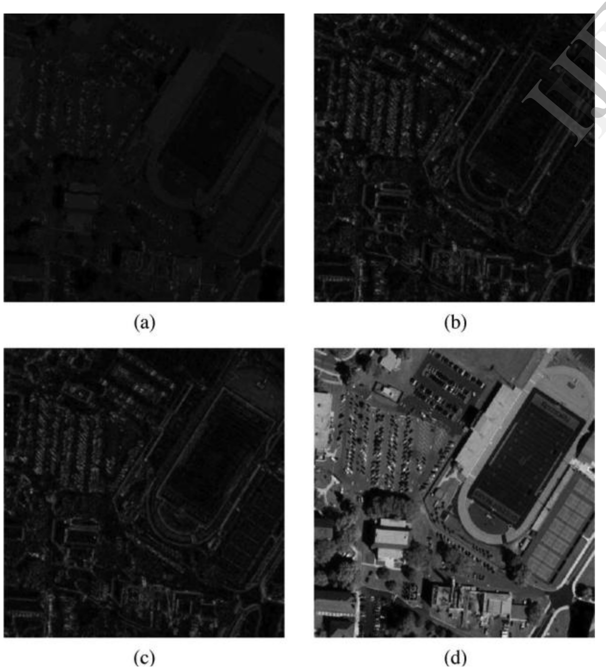

Figure 2: Comparison and difference between (d) the original high-resolution satellite image and (a) the proposed enhanced image, (b) the standard bi-cubic interpolation, and (c) the WZP- and CS-based image resolution enhancement technique.

3. Present Investigation

The aim of the work is to enhance the resolution, brightness and contrast of low resolution satellite images using Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD) and Global Mean and Variance (GMV). The DWT technique enhances the resolution of the satellite images whereas the SVD technique enhances the brightness of the satellite images wherein the GMV technique will enhance the contrast of the satellite images.This work leads to a better clarity for the output image compared with the input image. The enhancement is measured interms of PSNR (Peak Signal to Noise Ratio) values and MSE (Mean Square Error) values and the Mean and Variance values of both input and output images. An increase in PSNR value indicates resolution enhancement and an increase in the Variance indicates enhancement in contarst. These values are the basis for quantitative analysis.

We consider a high frequency low resolution satellite image as the input. We then apply histogram to this input image (GHE). Histogram equalization is a process of automatically determining transformation function which produces an output image with a uniform histogram. After histogram equalized image is obtained we then apply DWT to GHE image and input image, say, image 1 and image 2 respectively. In wavelet decomposition of an image, the decomposition is done first row by row and then column by column. Thus by DWT process the image will be subdivided into four bands. Of the four sub images obtained the one that is obtained by low-pass filtering the rows and columns is referred to as the LL image. The one that is obtained by low-pass filtering the rows and high-pass filtering the columns is referred to as the LH images. The one obtained by high-pass filtering the rows and low-pass filtering the columns is called the HL image. The sub image obtained by high pass filtering the rows and columns is referred to as the HH image. We also use lifting scheme as intermediate stage in DWT process.

Consider the LL image among the four images. We apply SVD to the LL band image of image 1 and image 2.

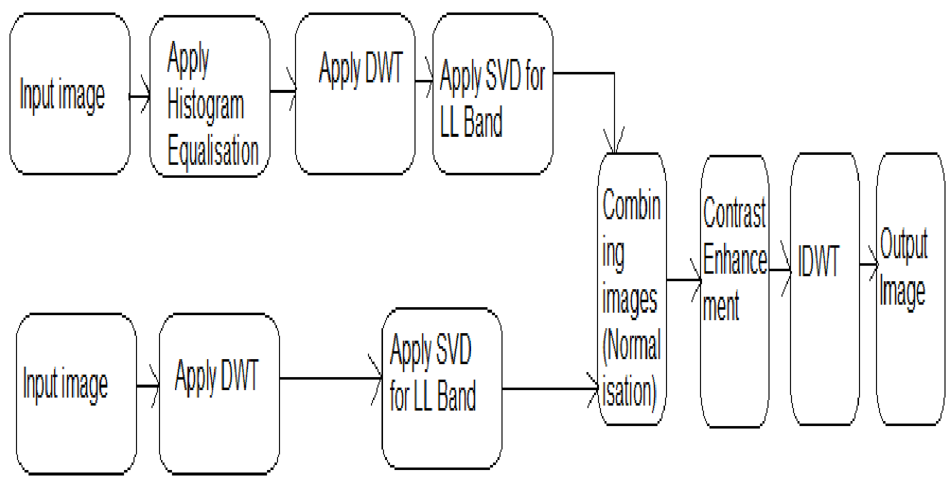

Figure 3: Block diagram

By singular value decomposition of an $m \times n$ real or complex matrix, M is factorized to the form:

$$M = U \sum V^* \tag{1}$$

where U is an $m \times m$ real or complex unitary matrix, Σ is an $m \times n$ rectangular diagonal matrix with non-negative real numbers on the diagonal, and V^* (the conjugate transpose of V) is an $n \times n$ real or complex unitary matrix.

The output is then combined by multiplying the values of image 1 and image 2 after the application of SVD on both images. Then we perform histogram equalisation on this output. Then we apply IDWT (Inverse DWT) technique. IDWT is applied to combine all these images to generate the final resolution-enhanced image. To achieve a sharper image, we use an intermediate stage for estimating the high frequency sub bands by utilizing the difference image obtained by subtracting the input image and its interpolated LL sub band.

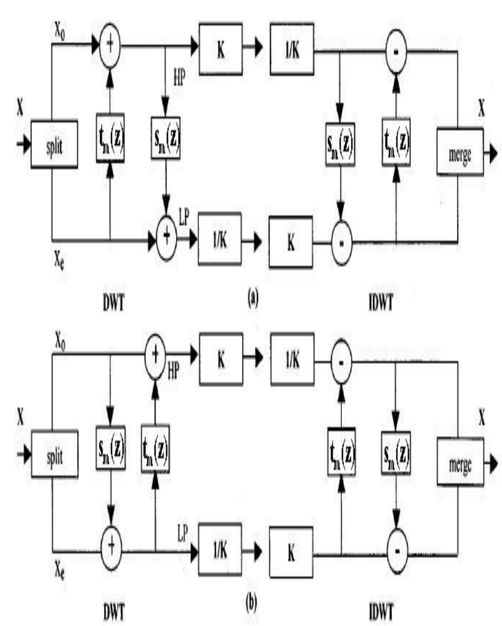

Figure 4: Lifting Scheme (a) Forward Transform, (b) Inverse Transform

The resolution and brightness enhanced image is then enhanced in contrast by the Global Mean and Variance technique. The image is factorized in the form:

Mean:

If S_{xy} denotes neighborhood or sub-image of a specified size centered at (x,y) , then

$$m_{s_{xy}} = \sum_{(s,t)\in s_{xy}} r_{s,t} \ \mathrm{p}(r_{s,t}) \qquad (2)$$

Mean of S_{xy} = summation of $r_{s,t}$ that belongs to (s,t) that belongs to S_{xy} X p of ($r_{s,t)}$)

$r_{s,t}$ = grey level at coordinates (st) in the neighborhood.

p($r_{s,t}$) = normalized neighborhood histogram

Variance:

The grey-variance of the pixels in region s_{xy} is computed as

$$\sigma^2_{s_{xy}} = \sum_{(s,t)\in s_{xy}} [r_{s,t} - m_{s_{xy}}]^2 \ \mathrm{p}(r_{s,t}) \qquad (3)$$

The output from IDWT process gives Brightness, Resolution and Contrast enhanced image due to the application of DWT , SVD and Histogram technique in the earlier stage of this enhancement process.

4. Results and Discussions

The proposed technique has been tested on several different satellite images. In order to show the superiority of the proposed method over the conventional techniques on the visual point of view, figures. 6-7 is included. In those figures with low-resolution satellite images, the enhanced images by using bi-cubic interpolation, enhanced images by using WZP and CS-based image resolution enhancement, and the enhanced image obtained by the proposed technique are shown. It is clear from the figure that the resultant image obtained, enhanced by using the proposed technique, is sharper than the other techniques [18].

Figure 7 shows that a satellite image in (e) enhanced by using the proposed technique is clearly sharper than the low resolution input image in (a) and (b), as well as the interpolated image in (c) and enhanced image by WZP and CS technique in (d).

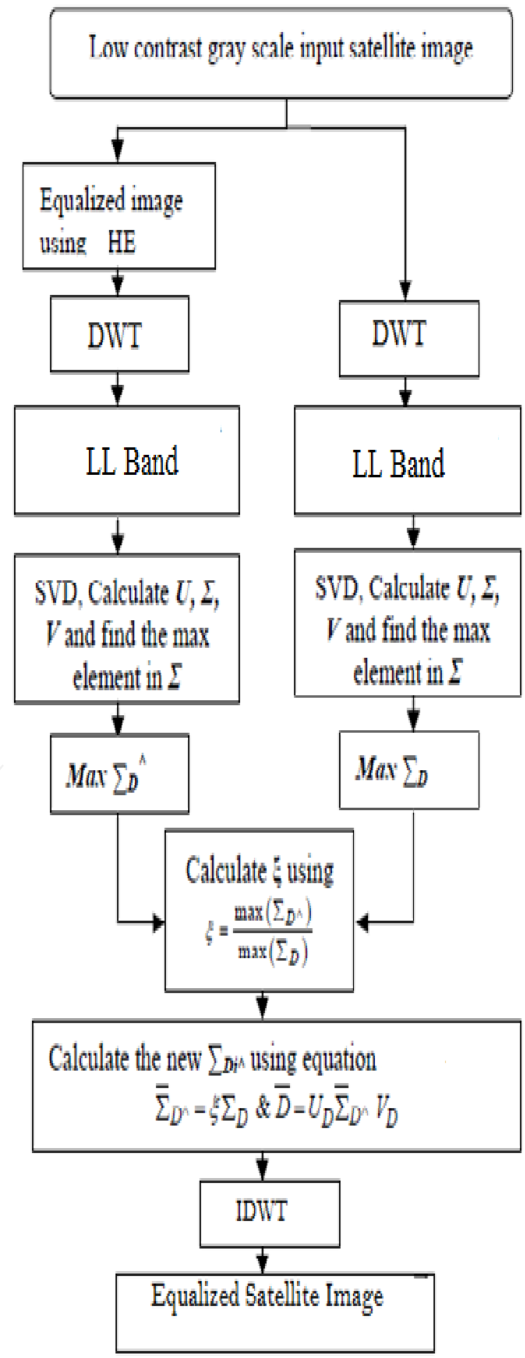

Figure 5: Proposed Flowchart for contrast enhancement

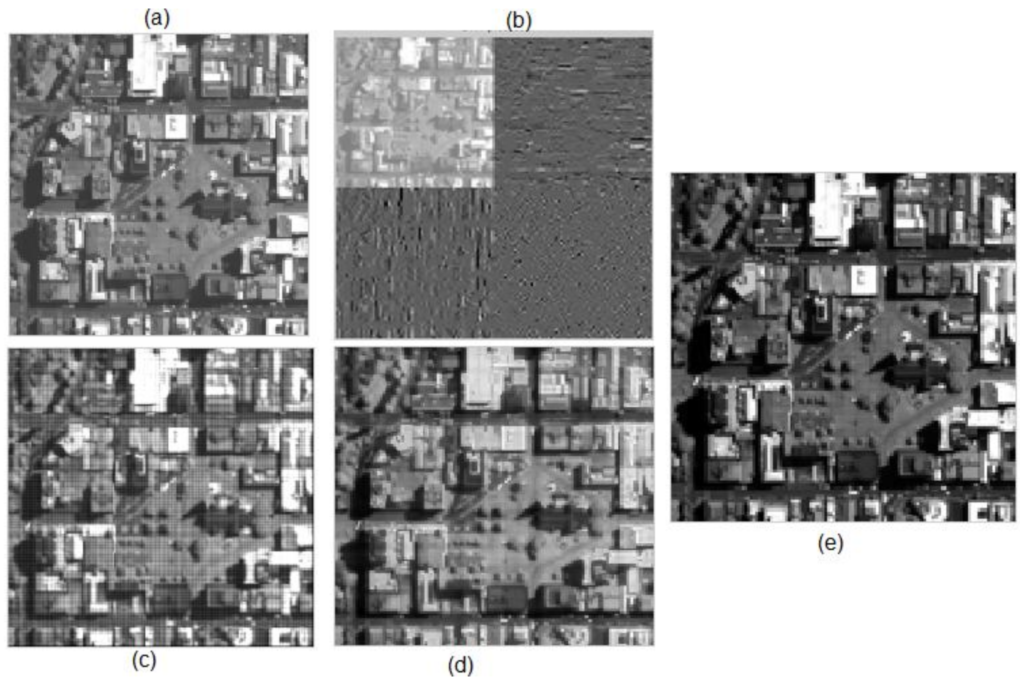

Figure 6: (a) Input image, (b) DWT applied image,(c) Resolution enhanced Image, (d) Brightness enhanced image ,(e) Contrast Enhanced image.

Various benchmark images with different features are used for comparison.

Not only with the visual comparison but also with the quantitative comparisons we can confirm the superiority of the proposed method. Peak signal-to-noise ratio (PSNR) and root mean square error (RMSE) have been implemented in order to obtain some quantitative results for comparison. PSNR is obtained from the following formula ;

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \qquad (4)$$

where *R* is the maximum fluctuation in the input image (255 in here as the images are represented by 8 bit, i.e., 8 bit gray scale representation have been used—radiometric resolution is 8 bit); and *MSE* is representing the MSE between the given input image I_{in} and the original image I_{org} which can be obtained by the following:

$$MSE = \frac{\sum_{i,j}\left(I_{in}(i,j) - I_{org}(i,j)\right)^2}{M \times N} \qquad (5)$$

where *M* and *N* represents the size of the images.

Clearly, RMSE is the square root of MSE, which can be calculated by the following:

$$RMSE = \sqrt{\frac{\sum_{i,j}\left(I_{in}(i,j) - I_{org}(i,j)\right)^2}{M \times N}} \qquad (6)$$

Table 1 is showing the comparison between the proposed method using Daubechies (db.9/7) wavelet transform with bilinear interpolation and some state-of-art resolution enhancement techniques, such as WZP, WZP and CS super-resolution technique and also the formerly proposed resolution enhancement technique by means of calculating PSNR. Table 2 is showing the comparison between the proposed method using Daubechies (db.9/7) wavelet transform with bi-linear interpolation and different conventional and state-of-art techniques by means of RMSE. The results of Table 2 are correlated with the results in Table 1, which is expected due to the definition of the PSNR in (2). Overall, the results in Tables1 and 2 show that the proposed method over performs the aforementioned state-of-art and conventional techniques.

The Table 3 shows the values obtained in Mean and Variance for the conventional methods and the proposed methods. The proposed method has also obtained a better value for the output image compared to the other conventional techniques.

As expected, highest level of information content is embedded in the original images. The main reason for the relatively high information content level of the images generated by the proposed method is due to the fact that the un-quantized input LL-sub band images contain most of the information of the original high-resolution image.

The application of SVD transform to the LL image obtained from DWT process increases the brightness of the image which is confirmed from the figure 8.The resolution and brightness enhanced image is enhanced in contrast by the Histogram Technique were in the Global Mean and Variance is being calculated to show the contrast.

The same input satellite image from the paper Resolution and Brightness Enhancement of Satellite Images using DWT and SVD is taken which has a PSNR value 24.3898 and MSE value 236.14. This image is a colour image of 640 × 480 pixel. This image is converted into gray scale image. On application of DWT with an intermediate state called interpolation, on this image, gives an enhanced image with a PSNR value 42.7752 and MSE value 3.4321, clearly indicating the enhancement for the image from the previous work.

Now by verifying the output and corresponding values we can confirm that resolution of the image has been enhanced twice that of the input image and by viewing the output we can estimate the enhancement in brightness and also the contrast of the image.

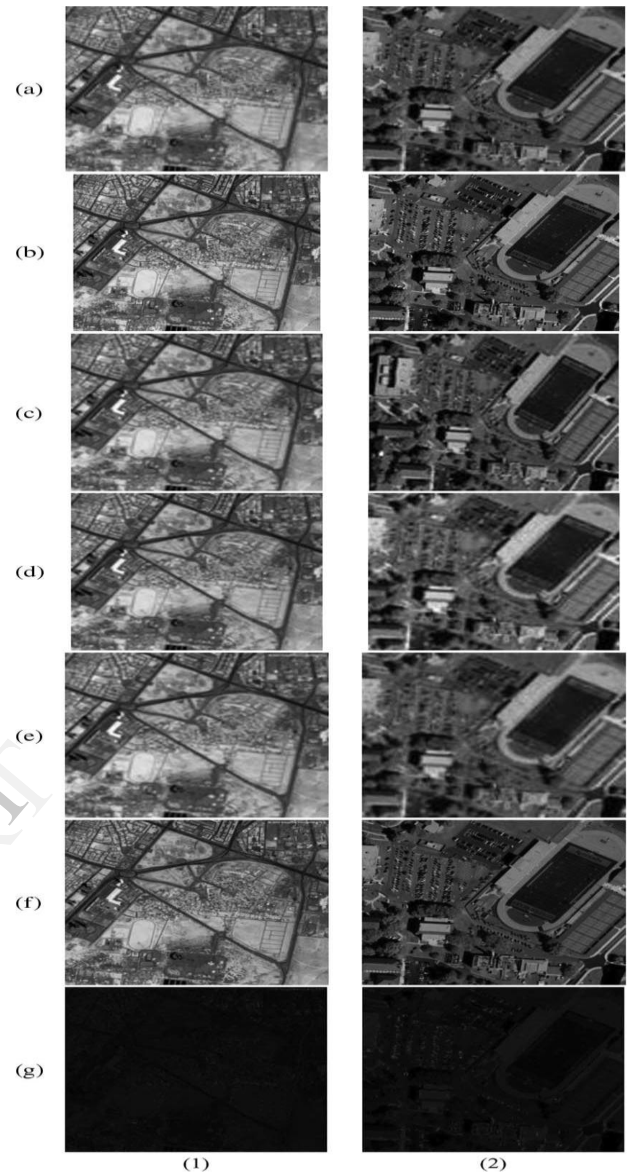

Figure 7: (a) Low resolution image obtained from down sampling of the high resolution satellite image through two cascaded DWT, (b) original high resolution satellite image, (c) bicubic interpolation based resolution enhancement,(d)WZP, (e) WZP and CS technique,(f) the proposed image resolution enhancement technique, and (g) the difference between the original high resolution satellite image and the image enhanced by proposed technique with enlargement from 128 × 128 to 512 × 512 [18].

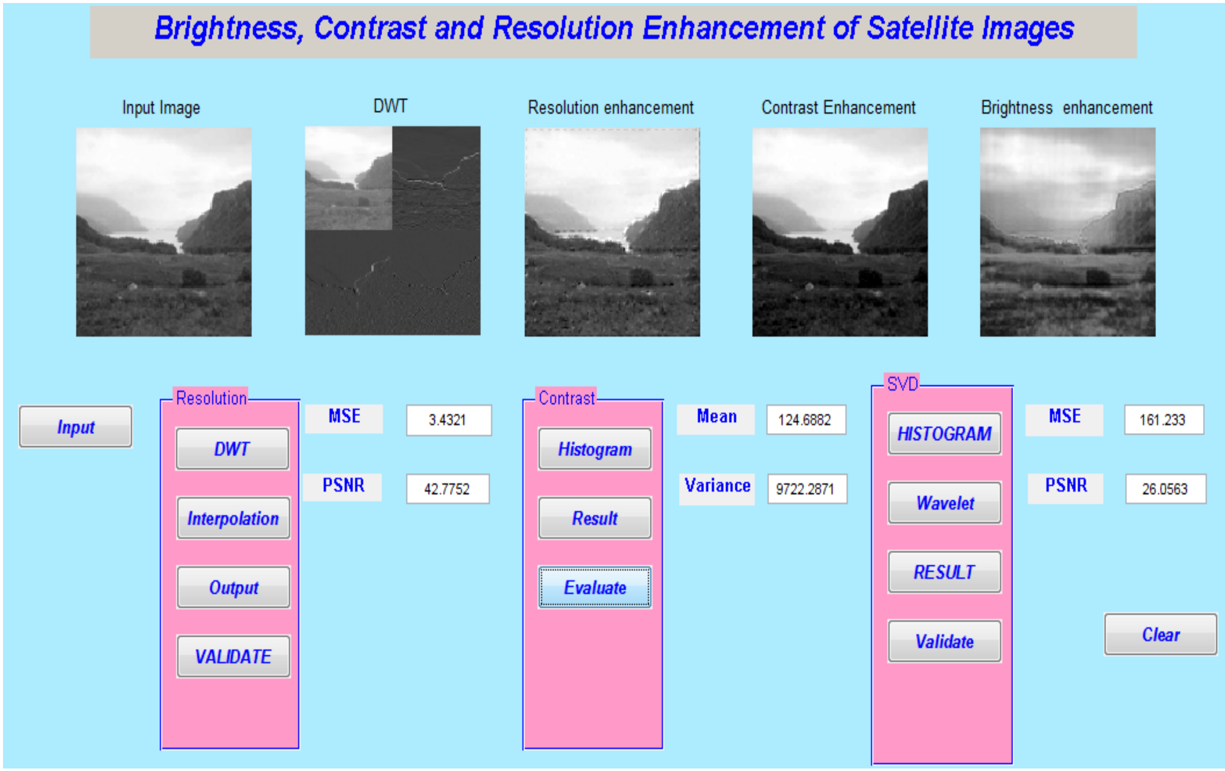

Figure 8: GUI diagram

Since the satellite images have application in various fields like in education, intelligence, meteorology, agriculture, geology, forestry, landscape, regional planning, biodiversity , conservation and warfare this enhancement in images can lead to improvement in all the above fields.

5. Conclusions

This paper proposed a new resolution enhancement technique based on the interpolation of the high-frequency sub band images obtained by DWT and the input image. This paper has proposed a contrast enhancement technique which is applied on the output image that has undergone SVD transform of LL band image obtained from DWT process.

The paper proposes a contrast enhancement of the output image obtained after enhancement in resolution and brightness. The proposed technique has been tested on well-known benchmark images, where their PSNR, RMSE and Mean and Variance and visual results show the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques. The PSNR improvement of the proposed technique is up to 18. dB compared with the standard bilinear interpolation and an increase of 4db from the technique proposed in DWT and SVD technique.

This work is mainly preferred for low resolution images though they give enhancement output to high resolution images as well. The precision and accuracy of enhancement will be more for low resolution images when compared with high resolution images. When this work is applied to high resolution images, we only get an accuracy of 70% but for low resolution images we obtain an accuracy of about 95% on the output image.

TABLE I

PSNR (DECIBELS) RESULTS FOR RESOLUTION ENHANCEMENT FROM 128 × 128 TO 512 × 512 (α =4) FOR PROPOSED TECHNIQUE COMPARED WITH CONVENTIONAL AND STATE-OF-ART TECHNIQUES

	PSNR(dB)	
Method / Image	**Fig 7-1**	**Fig 7-2**
Bilinear	23.67	20.91
WZP (Db.9/7)	22.91	21.76
WZP and CS SR	23.89	23.56
Demirel and Anbarjafari	27.08	24.73
DWT	30.22	26.03
DWT with bicubic interpolation)	39.92	39.05
Proposed Method	40.58	41.88

TABLE II

RMSE RESULTS FOR RESOLUTION ENHANCEMENT FROM 128 × 128 TO 512 × 512 (α =4) FOR PROPOSED TECHNIQUE COMPARED WITH CONVENTIONAL AND STATE-OF-ART TECHNIQUES

	RMSE	
Method / Image	**Fig 7-1**	**Fig 7-2**
Bilinear	4.09	4.79
WZP (Db.9/7)	4.27	4.56
WZP and CS SR	4.04	4.11
Demirel and Anbarjafari	3.36	3.85
DWT	2.80	3.57
DWT with bicubic interpolation)	2.56	3.33
Proposed Method	2.44	3.12

TABLE III

MEAN & VARIANCE RESULTS FOR ENHANCEMENT FROM 128 × 128 TO 512 × 512 (α =4) FOR PROPOSED TECHNIQUE COMPARED WITH PREVIOUSLY INTRODUCED RESOLUTION

ENHANCEMENT TECHNIQUE, AS WELL AS LOW RESOLUTION AND HIGH RESOLUTION ORIGINAL IMAGES

	Mean(μ)	
Method / Image	**Fig 7-1**	**Fig 7-2**
DWT with bicubic interpolation	105.86	115.84
Proposed Method	101.98	100.32

	Variance	
Method / Image	**Fig 7-1**	**Fig 7-2**
DWT with bicubic interpolation	6.139e+6	6.378e+6
Proposed Method	7.403e+6	7.138e+6

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