Satellite Image Enhancement using Discrete Wavelet Transform, Singular Value Decomposition and its Noise Performance Analysis

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***Abstract*— This paper introduce a new concept of satellite image resolution and contrast enhancement technique when the image is suffered from the noise and filtering it by various types of filters then the image is processed by discrete wavelet transform (DWT) and singular value decomposition (SVD) to get new modified contrast and resolution enhanced image. Satellite images are used in many applications such as geosciences studies, astronomy, and geographical information systems. Two most important quality factors of images are contrast and resolution, here this technique decomposes the input filtered image into the four frequency sub-bands by using DWT and then the high frequency subband images and input image have been interpolated along with this the technique also estimates the singular value matrix of the low–low sub band of histogram equalized image and input filtered image then normalize both singular value matrices to obtain brightness enhanced image. In, order to get the new image of better contrast and resolution all these subbands are combined using inverse DWT. The following procedure is done with different types of noises and different types of filters then they are compared with conventional image equalization techniques such as general histogram equalization (GHE), local histogram equalization (LHE) and also from state-of-the-art technique which is singular value equalization (SVE) and Discrete Wavelet Transform (DWT) and the experimental results show the supremacy of the proposed method over conventional and state-of-art techniques.**

***Keywords*— Bicubic interpolation, Non Local Mean filter (NLM), discrete wavelet transform (DWT), peak signal to noise ratio (PSNR), Singular value decomposition (SVD).**

I. INTRODUCTION

In Digital Image Processing the work is performed with digital images by the means of digital computer. It has many advantages above analog as having wider collection of algorithms and keeps away the problem of noise and signal deformation during processing. It's one of the best application is of improving the image quality with the aid of computer by maximizing the clarity, sharpness and detailed feature of interest towards extraction of information and further analysis of an image.

For the enhancement and removal of noise from an image, the digital image is subjected to different Image processing operations. The methods of Image-processing may be grouped into three categories such as [2], Image Restoration, Image Enhancement and Image Analysis.

Here is the discussion of subparts those consist in the proposed work such as, resolution contrast of an image these two factors are always an important issues in many image processing applications, such as satellite image resolution enhancement [3], feature extraction [4], video resolution enhancement [5]. Due to interpolation of an image the number of pixels in a digital image increases and its applications are widely used in many image processing applications, such as image resolution enhancement [6]–[8], multiple description coding [19] and facial reconstruction [10]. Wavelets are another term which plays a significant role in many image processing applications. The 2-D discrete wavelet transform of an image is performed by applying the 1-D discrete wavelet transform (DWT) along the rows first, and then along the columns. This operation gives results in four decomposed subband images named as low-low (LL), low-high (LH), high-low (HL) and high-high (HH). The frequency components of these subbands enclose the full frequency spectrum of the original image. Fig1. Shows the DWT of the input image which is taken from [12] Satellite Imaging Corporation.

NOISE MODELS

Generally, digital images are corrupted from noise during transmission, retrieval from storage and acquisition. The principal cause of noise occurrence is due to interfering in the channel which is used for the images transmission [14]. This can model a noisy image as follows:

$$C(x,y)=A(x,y)+B(x,y) \tag{1}$$

Where A(x ,y) is the original image pixel value and B(x ,y) is the noise in the image and C(x ,y) is the resulting noise image.

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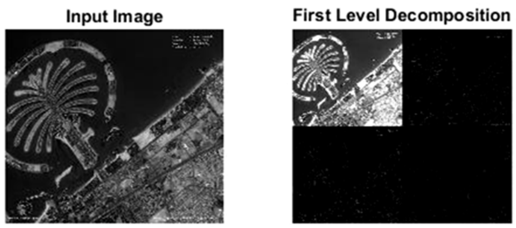


Fig 1: LL, LH, HL and HH sub bands of a satellite image obtained by using DWT

Gaussian Noise or Amplifier Noise: This noise has a probability density function [pdf] of normal distribution. It is also known as Gaussian distribution. Amplifier noise is the main part of the read noise of an image sensor, i.e of the constant noise level in dark areas of the image [20].

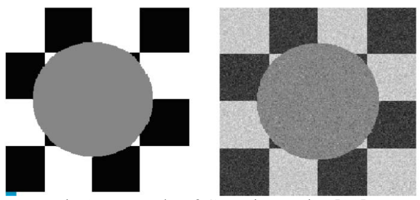


Fig.2: Example of Gaussian Noise [20]

Salt and Pepper Noise: The salt-and-pepper noise are also called shot noise, impulse noise or spike noise that is caused by faulty memory locations, malfunctioning pixel elements in the camera sensors, or there can be timing errors in the process of digitization. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions [20].

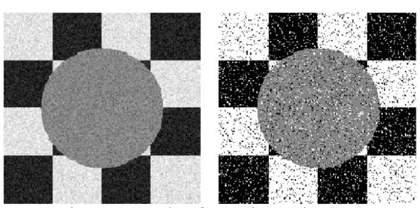


Fig.3: Example of Impulse Noise [20]

Poisson noise: Poisson noise or shot noise is a type of electronic noise that exists when the limited number of particles that carry energy, such as photons in an optical device or electrons in an electronic circuit, is small enough to give rise to detectable statistical fluctuations in a measurement [20].

Speckle noise: Speckle noise is also named as granular noise that basically exists in degrades the quality of the synthetic aperture radar (SAR) images and active radar. It raises the mean grey level of the local area. In SAR it is generally more serious, causing difficulties for image interpretation. It is introduced by coherent processing of backscattered signals from several distributed targets. In SAR oceanography [21], for example, speckle noise is caused by signals from the gravity-capillary ripples, elementary scatters, and manifests as a pedestal image, beneath the image of the sea waves.

FILTERS

Filtering in an image processing is one of the basic function which is used to achieve many tasks such as re-sampling, noise reduction and interpolation. The selection of filter is done by the nature of the task performed from the filter and type of the data which is to be used for operation. They are used to remove noise from digital image by restoring the details of an image and preserved its necessary part of image processing.

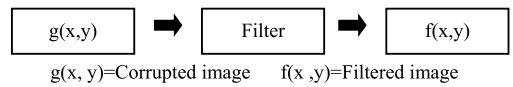


Fig.4: Filter description [15]

Median Filter: Median [22] Filter is a simple and powerful non-linear filter which is based on order statistics. It is one of the easy method which implement smoothing images. It is used for decreasing the amount of intensity variation between one pixel and the other pixel. In this filter, the pixel value of image is replaced by median value. This filter is used for de-noising different types of noises.

Wiener Filter: This filter is based on a statistical approach. Generally, all the filters are designed for a desired frequency response [23] where the wiener filter deals with the filtering of an image from a different point of view. Its goal is to reduce the mean square error as much as possible [17].
Fourier domain of the Wiener filter is:

$$G(u,v) = \frac{H*(u,v)}{|H(u,v)|^2\, P_s(u,v)+P_u(u,v)} \qquad (2)$$

Where *H*(u, v)* is complex conjugate of degradation function, *Pn (u, v)* is power spectral density of noise .Similarly, *Ps (u, v)* is power spectral density of non-degraded image and *H (u, v)* is a degradation function.

Non-Local Mean Filter: The self-similarity assumption can be exploited to de-noise an image. Pixels with similar neighborhoods can be used to determine the de-noised value of a pixel [11]. Weights are assigned to pixels on the basis of their similarity with the pixel being reconstructed. While assessing the similarity, the pixel those under consideration as well as its neighbor pixels are taken into account. Mathematically, it can be expressed as [23]:

$$NL[u](x) = \frac{1}{c(x)} \int e^{-\frac{(Ga*|u(x+.)-u(y+.)|\hat{}2)(0)}{h\hat{}2}} u(y)\,dy \qquad (3)$$

The integration is carried out over all the pixels in the search window. Where

$$C\ (x) = \int e^{-\frac{(Ga*|u(x+.)-u(y+.)|\wedge 2)(0)}{h\wedge 2}} dx \qquad (4)$$

C(x) is a normalizing constant. G_a is a Gaussian kerne1 and h is a filtering parameter [23].The Fig.5 shows the different types of noises and filters used in proposed work.

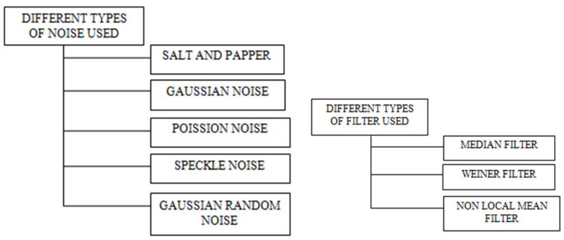


Fig. 5: Different types of Noise and Filters used [9]

This paper, propose a resolution and contrast enhancement technique on filtered image from the noise those using interpolated DWT high-frequency sub-band images with the difference image which get from the subtraction of interpolated LL subband and input image and then brightness enhancement is done by using SVD method on LL sub-band of both input and histogram equalized images, then the inverse wavelet transform is taken from the combination of these two techniques which is mentioned in [13] and [18].

The paper is organized as follows. Section I gives the brief introduction about the image enhancement techniques used here with different types of noise and filter models. Section II gives the method of proposed technique. Section III discusses the qualitative and visual results of the proposed method introducing different types of noises and filters in it and Section IV is the final section and concludes the whole paper.

II. PROPOSED WORK

The purpose of this work is to enhance the resolution and contrast of noisy filtered satellite images using DWT (Discrete Wavelet Transform) and SVD (Singular Value Decomposition) transform. The DWT technique enhances the resolution of the satellite image whereas the SVD technique enhances the contrast of the satellite image. Then this work gives more clarity for the output image compared with the input image. The enhancement is measured in terms of PSNR (Peak Signal to Noise Ratio), values of both input and output images. An increase in PSNR value indicates good quality of the image as compared to the input image .These values are the basis for quantitative analysis.

In proposed work here considered a high frequency low resolution satellite image as an input image on which different types of noises and filters combinations applied which is shown in Fig.5 and apply (GHE) histogram to this input image. Histogram equalization is a process of automatically determining transformation function which produces an output image with a uniform histogram. Then DWT to GHE image is applied and input image as image A and image B respectively. In wavelet decomposing of an image, the decomposition is done 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 subband obtained by low-pass filtering the rows and columns is referred to as the LL subband image then the next one is obtained by low-pass filtering of the rows and high-pass filtering of the columns is referred to as the LH subband image. The one which is obtained by high-pass filtering of the rows and low-pass filtering of the columns is called the HL subband image. The subband image which is obtained by high pass filtering of the rows and columns is referred to as the HH image.

Consider the LL image among the four subband images and apply SVD to the LL subband image of image A and image B. Then by singular value decomposition of an m×n real or complex matrix M is a factorization of the form [13]:

$$A=U*S*V^T \qquad (5)$$

where U is an m×m real or complex unitary matrix, Σ is an m×n rectangular diagonal matrix with nonnegative real numbers on the diagonal, and V* (the conjugate transpose of V) is an n×n real or complex unitary matrix. After that the transformation factor obtained by which new enhanced LL subband is formed. On the other hand to get the sharper image because the image is get blurred due to interpolation which is performed on DWT subbands of input image is subtracted by the input image and this difference image is added in the three subbands of the image names as LH, HL and HH which gives estimated subbands and those modified subbands again get bicubic interpolated.

Then the output is combined by resizing the new SVD enhanced LL subband to the size of interpolated estimated other three subbands by applying IDWT (Inverse DWT) technique and generate the final resolution and contrast enhanced image. In order to achieve a sharper image, we propose to 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. These steps can easily defined from the block diagram in Fig.6 and the output of IDWT process gives Brightness and Resolution enhanced image

due to the application of DWT and SVD technique in the earlier stage of this enhancement process.

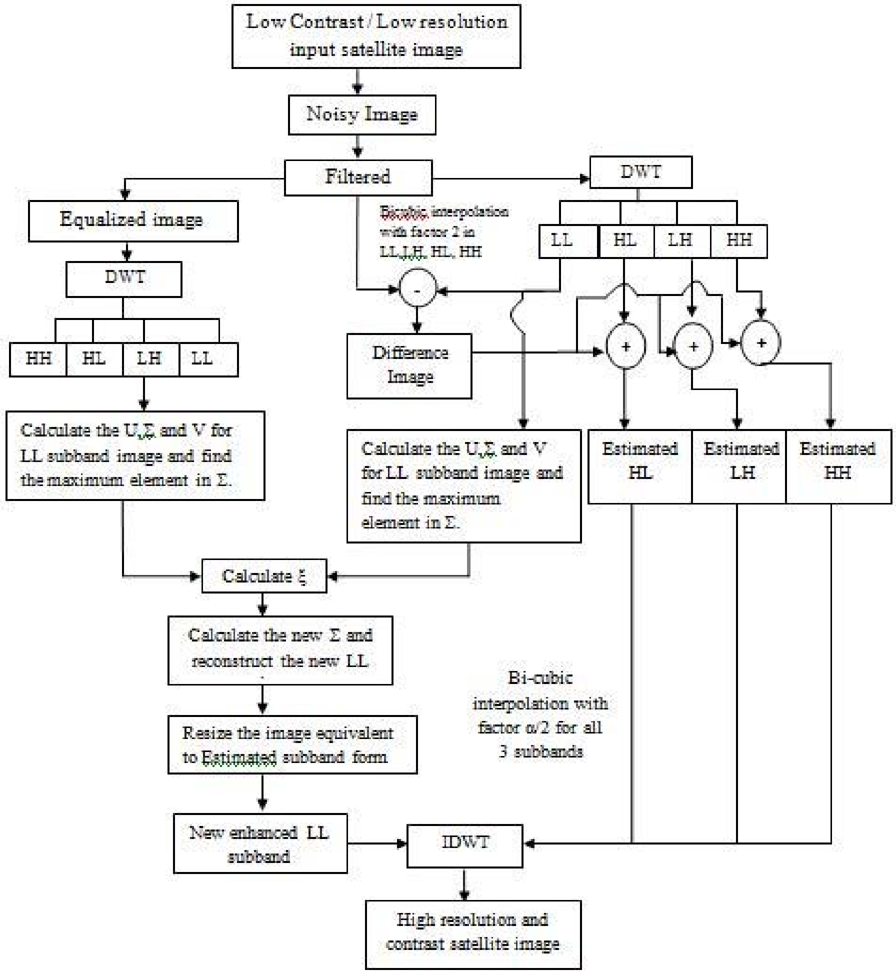


Fig.6: Block diagram of proposed contrast and resolution enhancement algorithm after introducing noise and filters.

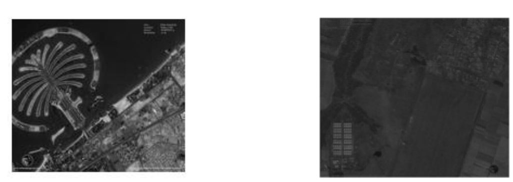
III. RESULT AND DISCUSSIONS

The proposed technique has been tested on different types of satellite images. In order to show the superiority of the proposed method which can also work for noisy image which is to be filtered and shows the result as an enhanced image can be obtained by the proposed technique. It is clear that the resultant image, enhanced by using the proposed technique, is sharper than the other techniques such as GHE (general histogram equalization), LHE (local histogram equalization), SVE (singular value equalization) and DWT (discrete wavelet transform). Not only visual comparison but also quantitative comparisons are confirming the superiority of the proposed method. Peak signal-to-noise ratio (PSNR) analysis has been implemented in order to obtain some quantitative results for comparison. PSNR can be obtained by using the following formula [1]:

$$PSNR=10log_{10}\left(\frac{R^2}{MSE}\right) \quad (6)$$

where R is the maximum fluctuation in the input image (255 is here as the images are represented by 8 bit, i.e., 8 bit gray scale representation have been used radiometric resolution is 8 bit)

Table 1 is shows the result in tabular form when all the techniques are applied after the image is filtered by different filters from different types of noises using Daubechies (db.9/7) wavelet transforms as in DWT and SVD [13] by means of calculating PSNR, for image 1.jpg. Similarly, Table 2 also show the result in tabular form for image 2.jpg .Overall, the results in Tables 1 and 2 show that for which type of noise gives best result of PSNR with which type of filter.



(a) Standard Test Image 1 (b) Standard Test Image 2

Fig.7: Two Standard Test Images [12]

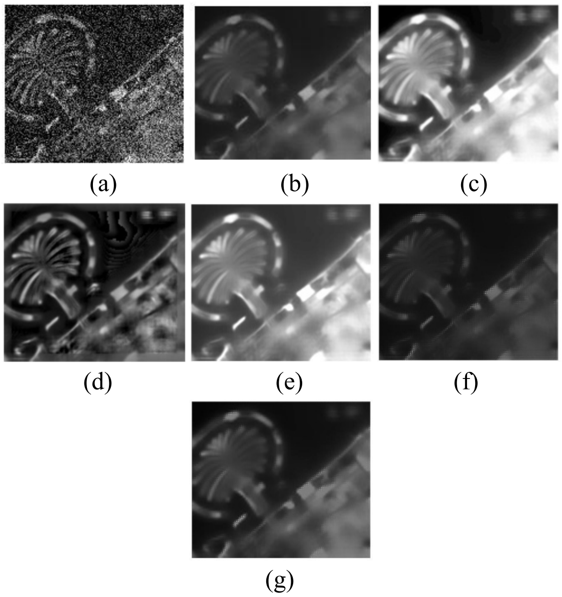


Fig.8: (a) Noisy image (Random Noise) (b) Filtered image as input image (Non local mean filter)(c) GHE image (d) LHE image (e) SVE image (f) DWT image (g) proposed method image.

TABLE 1: PSNR of image 1 after adding different types of noise and filtering it by different types of filters on given methods

TYPE OF NOISE	TYPE OF FILTER	PSNR VALUES				
		GHE	LHE	SVE	DWT	PROPOSED TECHNIQUE
SALT AND PEPPER NOISE	MEDIAN FILTER	7.38	16.18	8.46	18.53	22.21
GAUSSIAN NOISE	WEINER FILTER	7.45	15.18	8.72	18.21	25.44
POISSON NOISE	WEINER FILTER	7.05	15.22	8.14	17.41	22.19
SPECKLE NOISE	WEINER FILTER	7.26	15.57	8.43	17.99	21.71
GAUSSIAN RANDOM NOISE	NON LOCAL MEAN FILTER	7.63	17.40	8.97	20.39	28.39

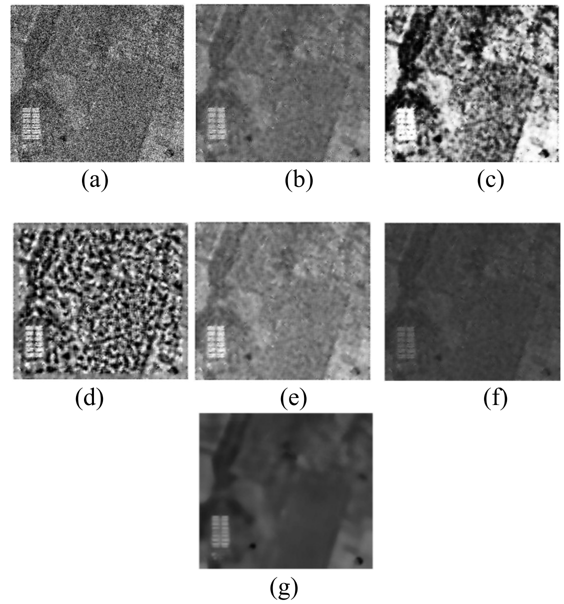


Fig.9: (a) Noisy image (Gaussian Noise) (b) Filtered image as input image (Weiner filter) (c) GHE image (d) LHE image (e) SVE image (f) DWT image (g) proposed method image.

TABLE 2: PSNR of image 2 after adding different types of noise and filtering it by different types of filters on given methods

TYPE OF NOISE	TYPE OF FILTER	PSNR VALUES				
		GHE	LHE	SVE	DWT	PROPOSED TECHNIQUE
SALT AND PEPPER NOISE	MEDIAN FILTER	8.97	11.04	11.9	15.86	19.95
GAUSSIAN NOISE	WEINER FILTER	9.12	11.06	12.1	15.96	17.18
POISSON NOISE	WEINER FILTER	7.71	9.74	9.88	12.71	14.85
SPECKLE NOISE	WEINER FILTER	7.49	9.47	9.50	12.19	15.29
GAUSSIAN RANDOM NOISE	NON LOCAL MEAN FILTER	9.16	12.25	12.2	16.21	15.73

Fig.8-9shows the noisy image from different noise on standard test images given in fig.7 (a),(b) represents filtered image respectively. The noisy image1 is obtained by Gaussian random noise with value of standard deviation as 50 and mean is 3 whereas (b) shows the filtered image by using different filters such as Non Local Mean filter for image1and GHE image shows in (c) and LHE image shows in (d) SVE and DWT image is shown in (e) and (f) respectively, the (g) shows the enhanced image by using the proposed technique.

The values are specified for the standard deviation 0.025 in case of speckle, Gaussian, salt and pepper noise. Here shows combination of three types of noise and three types of filters. Above mention two table shows that the proposed technique having maximum value of PSNR with every combination in all techniques. For image 1.jpg last combination of table 1 gives most enhanced result by having large value of PSNR as 28.39 and on the other hand for image 2.jpg the combination of Gaussian noise and Weiner filter gives the best value of 17.18 PSNR. Hence, it will vary from type of image as well as type of noise and filter.

IV. CONCLUSION

This paper has proposed a new technique in which noisy satellite image is filtered first with various combinations of noise and filters then the process followed which is combined form of resolution enhancement technique based on interpolation of high-frequency subband images obtained by DWT and input image along with the brightness enhancement technique based on SVD transform of LL band image obtained from DWT process, both of these process taking place parallel. Whereas, resolution enhancement works on HL, LH, HH subbands and contrast enhancement works on LL subband.

The proposed technique with different types of noise and different types of filters is performed and tested on satellite images, where their PSNR and visual results shows the superiority of the proposed technique having good performance of the Median Filter after de-noising for salt and pepper noise and wiener filter for all Speckle, Poisson and Gaussian noise is better whereas the combination of Gaussian random noise is filtered by Non Local Mean filter gives the specific result. This work is preferred for low resolution and low contrast images though they give enhancement output to high resolution images as well better contrast from the input image.

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