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Satellite Image Denoising using Discrete Wavelet Transforms

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Abstract: ***The paper "Enhancement of Satellite image Using Discrete Wavelet Transforms" makes use of both wavelet and adaptive histogram equalization techniques [7]. It is performed by make use of satellite images. By implementing this paper, enhancement is performed by increasing the resolution as well as its contrast. Thus the output image obtained is sharpened and is free from noisy content. First DWT [1] is applied to the input image; it decomposes the image into different frequency sub bands. Apply bicubic interpolation to these sub bands. Here an intermediate state is proposed for preserving more edge contents. In order to remove the noisy contents in the image here it uses adaptive histogram equalization technique. Thus a resolution enhanced denoised image is obtained using wavelet transform.***

Keywords: Discrete wavelet transforms (DWT), bicubic interpolation, adaptive histogram equalization.

1. Introduction

Satellite images are one of the currently used tools for many purposes. These images are very useful for forecasters as it gives a clear and accurate result of what is happening in the atmosphere. It is mainly focussing on to show what cannot be measured or seen. The most important characteristics is error free. Satellite images were made from pixels. The first image taken by satellite Explorer6.The photo was taken when satellite was above the surface of the earth. The data of satellite image consisted of 8 bands. Among these 1-3 specifies visible light, 4-5 specifies infrared, band 7 has a spatial resolution 30 meter of dot size and finally band 8 specifies panchromatic band. Each image would contain 3.8 kilobyte of data requires storage of 8 bits. It can cover the width area at 183 km length.

Satellite images are mainly used in many applications such as in geosciences studies, astronomy, weather forecasting and in geographical systems. The other applications includes in meteology, agriculture, forestry, super resolution. Satellite images are usually taken from low resolution cameras. They suffer from low illumination problem. Surveillance cameras would not have the ability to take accurate images .It is because of the relative motion between camera and vehicle. One of the problems that it faces today is resolution and the other is the variation in the intensity values which includes brightness, contrast, colour etc. One of the commonly used techniques for image resolution enhancement is interpolation. Interpolation has been widely used in many images processing application. Interpolation [6] is a method to increase the number of pixels in a digital image. The bicubic interpolation uses sixteen (4 × 4) neighbouring pixels for estimation which is depicted here.

The main loss of an image after being resolution enhanced by applying interpolation on its high frequency component is due to the smoothening caused by interpolation. Hence, in order to increase the quality of enhanced images, preserving the edges is essential. This problem can be solved by interpolating images in wavelet domain. This technique is used here and implementing the paper based on discrete wavelet transform. The major advantage of wavelet transform is it can perform multi-resolution analysis of a signal with localization in both time and frequency.

Figure 1: Input image for DWT method

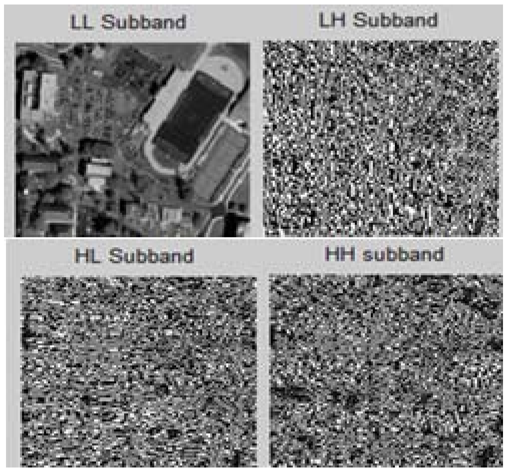

Figure 2: Decomposition of image into bands

For image enhancement process, there are two domains has been taken into consideration one is image domain and transform domain. Image domain determine which interpolation is used whereas transform domain determine which transformations used in the enhancement. Transform theory plays a fundamental role in image processing, as working with the transform of an image instead of the image itself may give us more in sight in to the properties of the image. Two dimensional transforms are applied to image enhancement, restoration, encoding and description various types of transforms are used for the image enhancement. They are Fourier transform and wavelet transform. There are a lot of differences between these transform , the major problem with Fourier transform is it is unable to pick local frequency content and it has a hard time representing functions that are oscillatory. These problems can be solved by the wavelet transform. The major advantage of wavelet transform is it can perform multi-resolution analysis of a signal with localization in both time and frequency.

As considering the previous techniques the main problem is the loss of high frequency components. Without preserving it, the ultimate goal to get a good resolution image cannot be achieved. It is because a high frequency sub bands component contains the edge information, which cannot be preserved so in order to retrieve a high quality image, preserving the edge is essential. Moreover as this paper makes use of the satellite image there will be a possibility of noisy content in the image. .Moreover here while boosting the high frequency components, the noisy elements too are boosted. This paper proposes a resolution enhancement technique using bicubic interpolation and then sharpens the enhanced image using adaptive histogram technique. First the input image is decomposed using DWT into four different sub bands. It is depicted in fig 1 and fig 2. Then apply bicubic interpolation to these sub bands. Then the high resolution image undergoes denoising technique. Thus remove those coefficients related with noise rather than the original image. This corrected image obtained enhanced visual quality enhanced image is obtained. The remaining section of this paper is organised as follows Section II gives an idea of various methods that are present today. Section III describes the details about resolution enhancement and adaptive histogram, finally section IV concludes the paper.

2. Various Techniques

Hasan Demirel and Gholamreza Anbarjafari [2] proposed about Complex wavelet transform (CWT) which is one of the recent wavelet transforms used in image processing. Here, dual-tree CWT (DT-CWT) used to decompose a low-resolution image into two complex value low frequency sub-band images and six complex valued high frequency images. These high frequency bands are obtained using direction selective filter as it gives peak magnitude responses for the image features when it orients at +75 ,+45,+15,-15,-45,-75 degrees.. The advantage of the paper is that it is shift invariant, limited redundancy and good directional selectivity. The problem with it is that there is a loss of high frequency components and computational power is higher.

Gholamreza Anbarjafari and Hasan Demirel [4] makes use of DWT for decomposing an image into different sub-band images which includes Low-Low, Low-High, High-Low, High-High. The high frequency sub-bands contain edge information while LL contains the low resolution of the input image. It overcomes the disadvantages that are proposed in the previous paper by performing interpolation on isolated high-frequency components will preserve more edge information. The drawback is that it uses the original image only for obtaining LL band from it and it does not consider the high frequency component present in the original image. So there is a loss of some of the high frequency components.

In this paper [1], DWT has been employed in order to preserve the high-frequency components of the image. DWT separates the image into different sub band images, namely LL, LH, HL, and HH. High-frequency sub-bands contain the high-frequency component of the image and low frequency images are the low resolution of the original image. The interpolation cans be applied to these four sub band images. Thus four interpolated sub bands are obtained .In order to preserve more edge information i.e. obtaining sharper enhanced image an intermediate stage is proposed. This intermediate stage is obtained by taking the difference between interpolated LL sub-bands with a factor 2 and input low resolution image. Thus a difference image is obtained and this image contains only high frequency components. Hence, this difference image can be used in the intermediate process to correct the estimated high-frequency components. Finally the result is combined by make use of IDWT. The proposed paper overcomes the disadvantages that are specified in the above papers by considering LL band for calculating the difference image.

3. Proposed Method

The two problems that have to be faced while performing with satellite images are solved by the proposed paper. In the first step, perform resolution enhancement and in the second step image sharpening. The first problem is solved by using DWT and interpolation technique while the other is performed by adaptive histogram technique

3.1 Resolution enhancement

Satellite images are used in many applications now days. But while performing enhancement it may affect the performance of the system. In order to overcome interpolation had been imposed. But, while doing, this occurs blocking affects and of low quality image. The main loss in image is due to the absence of edge component. So in order to preserve the edge component, DWT [1], is used.

In the proposed work, the mother wavelet is selected. Here daubechies 9/7 is used as mother wavelet [5] and then apply discrete wavelet transformation to the low resolution image. DWT [1] decomposes the input image by convolving the input low resolution with the respective mother wavelet and produce four different frequency sub-bands. This process is done using low pass and high pass filters. After each filtering, sub-sampling is done. The frequency sub-bands obtained by transformation are Low- Low (LL), Low-High (LH), High-Low (HL) and High-High (HH). The LL sub-band gives the

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image information and the remaining high frequency sub-bands gives the edge information in the horizontal, vertical and diagonal direction. Because of sub-sampling after each filtering, the resultant sub-images have the quarter size of the original image.

For enhancing the resolution (increasing the no of pixels), apply bicubic interpolation [8] to each of the four sub-bands. Here bicubic interpolation is performed. It uses neighbouring 16 pixels for the estimation of unknown pixel and it approximates the local intensity values using bicubic polynomial surface. Since the 16 pixels are at various distances from the unknown pixel, closer pixels are given higher weighting in the calculation. It produces noticeably sharper images than the previous method. Thus after apply bicubic interpolation four interpolated sub-bands are generated. They are interpolated LL band, interpolated LH band, interpolated HL band, and interpolated HH band. Then find an intermediate stage which is obtained by taking difference between interpolated LL bands with low resolution input image. This intermediate stage is called difference image. The main highlight of this paper is, it uses an LL band which is ignored in the previous techniques. To estimate more high frequency component adding this difference image with each of the interpolated high frequency components. Thus an estimated high frequency sub-band images are obtained.

Apply inverse discrete wavelet transform is used for combining all the sub-bands. That is, again apply bicubic interpolation to the each of the estimated high frequency sub-bands and the input low resolution image in order to obtain the required size for IDWT. Then combine the estimated sub bands and the input image using Inverse DWT. Finally an enhanced image is obtained.

The process of adding the difference image as an intermediate stage will generates sharper and clearer images. This sharpness is boosted by the fact that, the interpolation of isolated high-frequency components will preserve more high-frequency components than interpolating the low-resolution image directly.

Steps
1. Set the mother wavelet as daubechies 9/7
2. Apply 1-DWT along rows of the input image and then apply along columns of the resultant image.
3. Apply interpolation to the sub bands obtained from the above steps and finds a difference image
4. Adding this difference image in order to obtained an estimated high frequency components
5. Using inverse DWT combined all these high frequency components with the input images.

3.2 Contrast Enhancement

The output obtained from the resolution enhancement is taken as input to contrast enhancement. The tool used for this is adaptive histogram equalisation. The main problem with the satellite image is noise, so to cope with this problem, here design an effective method to remove the noise related coefficients (i.e., increase the contrast of particular regions) from the output images.

In order to increase the contrast of the resolution enhanced image apply adaptive histogram equalisation technique to this image. It is a technique in image processing used to improve the contrast of particular image. It differs from the ordinary histogram [7] by the methods which is done on the images that is, this method computes several histogram and uses them to redistribute the contrast value of the image.

This method is capable of improving the images local contrast, so it brings out more detail about the image. The generalisation of adaptive histogram equalisation is also known as contrast limited adaptive histogram equalisation (CLAHE)[7].This will address the problem of noise amplification. The operation of CLAHE is first done on the input image that is, it mainly concentrates in the smaller regions of image and it is called as tiles. The existing denoising technique concentrates on the entire image. Here each tile's contrast is enhanced and the histogram of the output region approximately matches the histogram specified by the distribution parameter. To eliminate the artefacts in the boundaries, apply interpolation technique to the neighbouring tiles. The contrast in homogenous areas can be limited to avoid the amplification of noise in the image. Thus we get an enhanced high resolution with denoised image.

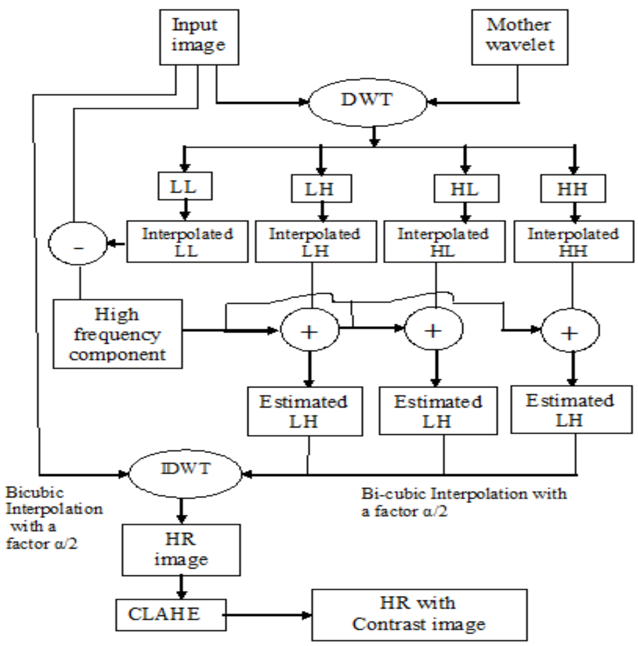

Figure 3: Architecture of the proposed method

The Fig. 3 explains that DWT separates the image in to different sub band images, namely LL, LH, HL, and HH. High-frequency sub-bands contain the high-frequency component of the image and low frequency images are the low resolution of the original image. The interpolation cans be applied to these four sub band images. Thus four interpolated sub bands are obtained. In order to preserve more edge information i.e. obtaining sharper enhanced image an intermediate stage is proposed. This intermediate stage is obtained by taking the difference between interpolated LL sub-bands with a factor 2 and input low resolution image. Thus a difference image is obtained and this image contains only high frequency components. Hence, this difference image can be used in the intermediate process to correct the estimated high-frequency components. This estimation is performed by adding the interpolated high frequency components with the difference images. Thus an estimated high frequency component is obtained and this estimated high frequency sub-bands is again interpolated with bicubic interpolation with factor α/2 in order to reach the required size for IDWT process. Thus using inverse DWT combine the interpolated input image with these estimated high frequency components and obtained a high resolution images. Apply adaptive histogram equalisation to this high resolution images in order to increase the contrast of the particular image, then we get high resolution with high contrast image.

4. Results and Discussion

The main objective of the system is to enhance the resolution as well as the contrast. The entire system was simulated using Matlab. The proposed system is tested using different images. For the purpose of showing that the proposed system will give better result, here a comparison study is performed. For comparing purpose, the various techniques such as DASR [4], DWT SWT [3], daubechies 9/7 and also perform the system by make use of another mother wavelet namely symlet. The results obtained are subjected to estimation to know how far the image is enhanced. For that here used mean square error and peak signal to noise ratio which are the two customary impersonal criterions to evaluate processed image quality. They are described:

$$MSE = \frac{1}{MN}\sum_{1\le I\le M}\sum_{1\le J\le N}\{ f'(i,j) - f(i,j) \}^2$$

$$PSNR = 10\log_{10}\frac{255^2}{MSE}$$

where f '(i, j) denotes the image which is the low resolution image or the image that has been processed, f (i, j) denotes the original image (enhanced image) and M,N denotes the length and width of the image, respectively. PSNR has a definite negative correlation with MSE. Generally, PSNR is bigger; it is considered that the processed image is closer to the original.

4.1 DASR Technique

DASR [4] is performed by make use of DWT technique. Here first the input image undergoes DWT operation which generates four sub bands such as LL, LH, HL and HH. The LL is ignored. Then each of the high frequency sub band are interpolated. Also interpolate the input image for getting the LL band. It is because LL is the low resolution of the input image. So better interpolate the input image rather using LL directly. Then combine all these bands using IDWT. Then perform contrast enhancement.

4.2 DWT SWT Techniques

In DWT SWT [3], it decomposes the input image by using DWT and SWT separately. Thus it generates a pair of LL, LH, HL, and HH. The bands from DWT undergo interpolation inorder to attain the size of SWT bands. The LL, LH, HL, HH from SWT need not interpolate as it has the same size as that of the input image. Then combine each of the high frequency sub bands and generate estimated LH, HL, and HH. Then interpolate the input image for getting the LL band. These all have to combine by using IDWT. Then perform contrast enhancement.

4.3 Proposed Technique

Its details are explained above. As a purpose of comparison, here perform the proposed technique by using two mother wavelets namely symlet and daubechies 9/7. From the results obtained, it is clearly understand that the proposed system can work well with other mother wavelets too. Moreover it gives better results while performing with daubechies 9/7.The details are specified in the table 6.1 and in table 6.2.

For each of these techniques, calculate PSNR, MSE and Entropy. By performing with these techniques, it is clearly shows that the system with daubechies 9/7 will give better result. The results obtained are subjected to estimation to know how far the image is enhanced. Mean square error and peak signal to noise ratio are two customary impersonal criterions to evaluate processed image quality. They are described as:

The psnr value enumerated in the following table indicate that the propose method is able to enhance the images while preserving almost all image details. It can also be observed visually that the proposed system is quite effective than the others. Table 6.1 gives details about the comparison of PSNR for the four methods. It is performed by using DASR technique, DWT SWT technique and the proposed technique. The proposed technique is performed by using two mother wavelets namely symlet and daubechies 9/7. It shows that daubechies 9/7 gives high psnr value while experiment with three different images.

Table 1: PSNR results for enhancement of resolution from 128*128 to 512 *512 (α=4) for various methods as compared with the proposed technique

Images	*DASR*	*DWT SWT*	*Symlet*	*Daubechies 9/7*
Image 1	24.7212	24.6994	24.7509	37.4138
Image 2	24.1654	24.1508	24.1939	34.4767
Image 3	24.1467	24.1342	24.1739	34.5173

The table 6.2 shows values for the comparison of MSE for the four methods. It is performed by using DASR technique, DWT SWT technique and the proposed technique. The proposed technique is performed by using two mother wavelets namely symlet and daubechies 9/7. It indicates that daubechies 9/7 gives low error value while experiment with three different images.

Table 2: MSE results for enhancement of resolution from 128*128 to 512 *512 (α=4) for various methods as compared with the proposed technique

Images	*DASR*	*DWT SWT*	*Symlet*	*Daubechies 9/7*
Image 1	8.5501	8.5716	8.5217	1.9834
Image 2	9.1141	9.1294	9.0843	2.7813
Image 3	9.1337	9.1468	9.1051	2.7677

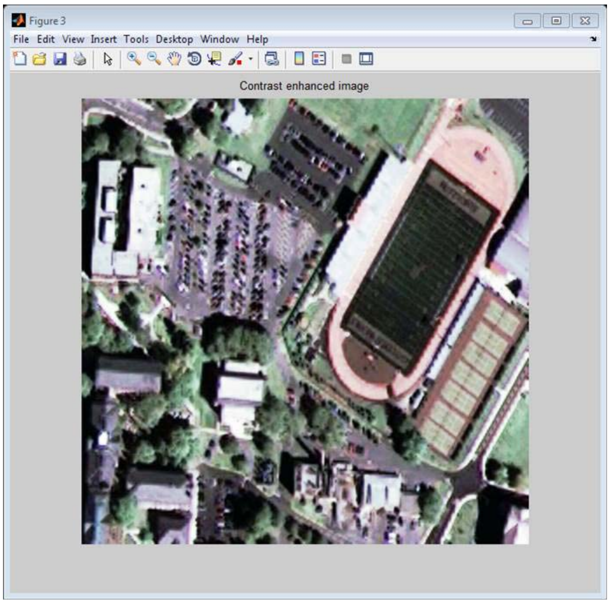

Figure 4: Contrast Enhanced Image for the proposed method

5. Conclusion

The main challenges in satellite image processing include low resolution and noise. So to enhance such low resolution images apply some conventional interpolation techniques. But it produces artefacts such as noise and the resultant image is blurred. To overcome such problem interpolation using wavelet domain is implemented. The wavelet based method enhanced the image and produce better results than the other techniques. This technique generates significantly sharper and clearer final image. This sharpness is boosted by the fact that, the interpolation of isolated high frequency components. But still remains certain problem such as noise and it is acquired during image acquisition phase or from other sources. So to remove the noise, contrast enhancement is implemented and for that adaptive histogram equalization is applied on the images. This will give get much better results.

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