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A Review on Satellite Image Enhancement Techniques using Wavelet Transform and Interpolation

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Abstract: Satellite images are used in various field of research and applications. The major limitation of satellite images are its resolution. Therefore image resolution enhancement is very necessary and first step in image processing. To modify an image under some consideration so that the obtained image is superior than the original image for specified application is image resolution enhancement. Resolution enhancement of images can be performed in different domain such as Spatial and Transform domain. Images with high resolution give better result for a specific application. Different image enhancement methods based on transform domain are Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Stationary Wavelet Transform (SWT), DWT with SWT, Dual-Tree Complex Wavelet Transform (DT-CWT), DT-CWT with cycle spinning. In this paper, it has been discussed about different image enhancement techniques based on transform domain and interpolation methods. All the techniques are discussed and compared on satellite benchmark images and the analytical results of all these shows supremacy of methods over each other.

Keywords: Satellite images, DWT, DCT, SWT, DWT with SWT, DT-CWT, DT-CWT with CS, Interpolation.

I. INTRODUCTION

Nowadays enhancement of images is very important in image processing. Because of requirement of good quality of images are increasing day by day. Since images are used in various applications such as object recognition, medical imaging, biometrics and astronomy. Apart from all these applications satellite images are also used in monitoring of Infrastructural projects and in global positioning systems. Among the several factors most important factor to increase image quality is resolution. Interpolation is a known method to enhance the resolution of image. The mainly used interpolation techniques are Nearest neighbour interpolation, Bilinear interpolation, Bi-cubic interpolation. Among the three interpolation methods bi-cubic interpolation is most commonly used because it gives sharper image but bi-cubic interpolation is more sophisticated than nearest neighbour interpolation and bilinear interpolation. Images can be enhanced using a combination of transform techniques and interpolation methods. For edge enhancement wavelet transform can be used very effectively. Since most of the information is contained in edges, so edge enhancement is very important. In transform domain methods different algorithms that are based on DWT, SWT, SWT with DWT, DT-CWT, DT-CWT using Cycle Spinning (CS) are used. Wavelet transform which uses wavelets performs an important role in image resolution enhancement.

This paper is organised as follows:

Section I. Introduction. Section II. Discussion of different satellite image enhancement techniques based on transforms domain and interpolation. Section III. Evaluation Methods. Section IV. Conclusion.

II. IMAGE RESOLUTION ENHANCEMENT METHODS BASED ON TRANSFORM DOMAIN

A. Discrete wavelet transform

DWT is a very popular technique to preserve the high frequency components of an image. In this 2D wavelet decomposition has been performed along the rows and then result is decomposed along the columns of an image. DWT technique of resolution enhancement decomposes the input image into four subbands that are low-low (LL), low-high (LH), high-low (HL) and high-high (HH). The input low resolution image and high frequency subband images have been interpolated using bi-cubic interpolation method. Resolution enhancement of an image using wavelets is a more recent and new subject because many new algorithms are proposed. The intermediate stage is composed of difference

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between the input low resolution image taken directly and interpolated LL sub band image. After than the difference image is added with interpolated high frequency subband images LH, HL and HH. The required output image is obtained by inverse discrete wavelet transform (IDWT). IDWT has been estimated by using subband images and low resolution input image using bicubic interpolation by a factor α/2. The output of IDWT provides enhanced high resolution image. The obtained high resolution image gives sharper image and contains more edge information. Thus the quality of the image increases. The DWT technique gives sharper image quality but loses of high frequency components occur.

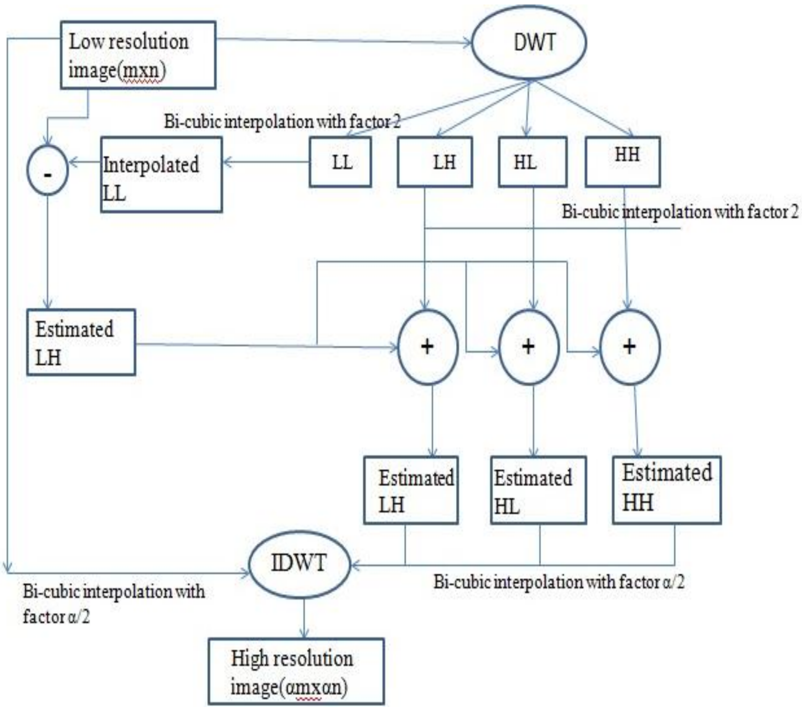

Fig1. Block diagram of DWT based resolution enhancement method

B. Discrete cosine transform

Discrete Cosine Transform (DCT) technique is mostly used for compression of video and audio to reduce the storage requirement. In addition to this it is also used for image resolution enhancement. DCT technique has the property of energy compaction and concentration because it preserves most of the power in its lower frequencies. DCT coefficients are obtained from low resolution input image and zeros are padded. After than inverse DCT (IDCT) has been applied on resulting coefficients which gives high resolution image. The drawback with DCT technique is that it provides poor contrast of the resultant image.

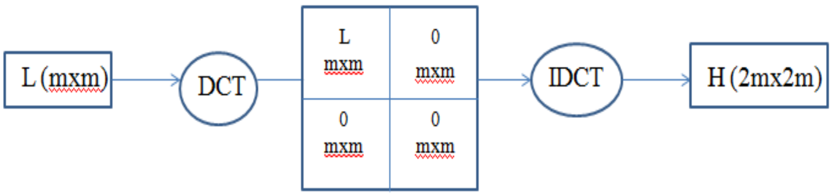

Fig 2. Block diagram of DCT based resolution enhancement method

C. Stationary wavelet transform

The stationary wavelet transform (SWT) is also a wavelet transform algorithm which is used to overcome the lack of translational invariance of DWT. SWT technique is similar to DWT except in the manner that it does not use downsampling. Because of that the size of subbands will be same as input image. In SWT the low resolution input image in addition with high frequency LH, HL and HH subband images are considered. For high resolution output image inverse wavelet transform has been applied. Bi-cubic interpolation has been preferred for image resolution enhancement because it provides less blurring and smooth edges compared to other methods of interpolation. SWT technique preserves the high frequency components of the input image, minimizes loss and provides smooth image but SWT is more complex compared to DWT technique.

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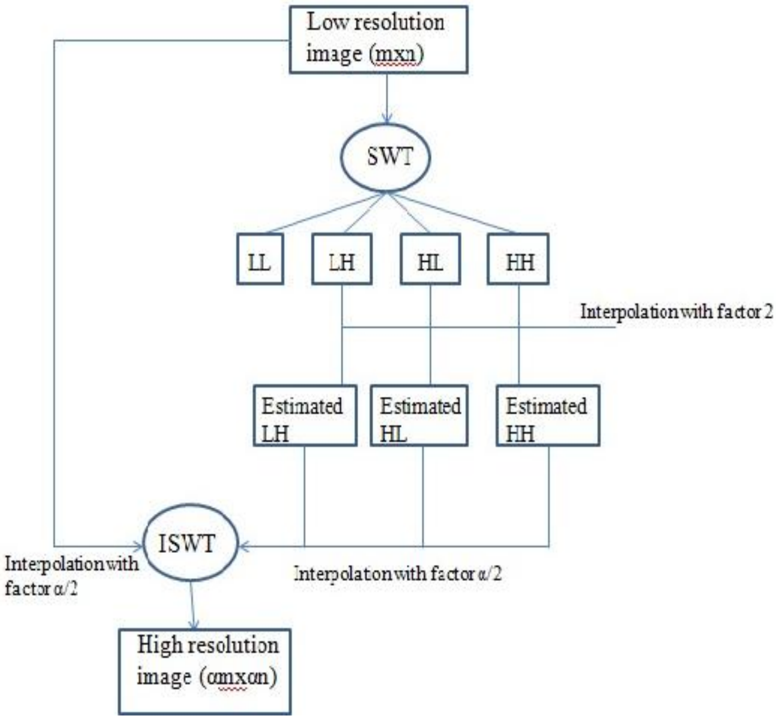

Fig 3. Block diagram of SWT based resolution enhancement method

D. Stationary Wavelet Transform with DWT

In this image enhancement technique SWT and DWT are combined which provides a better resolution enhanced satellite images. Edges of an image play a very important role in image enhancement. While using interpolation most of the losses occur in high frequency components i.e. edges. So for high resolution image edge preservation is very necessary. Bi-cubic interpolation has been applied to high frequency subbands which are obtained by using DWT. These subbands are combined with subband images which have been obtained by using SWT to generate high frequency subband images. After applying IDWT on the estimated subband images and low resolution input image, high resolution output image has been obtained. The information loss, which occurs due to downsampling of DWT, has been avoided in this technique because SWT does not employ downsampling like DWT. SWT with DWT method may lead to distorted image.

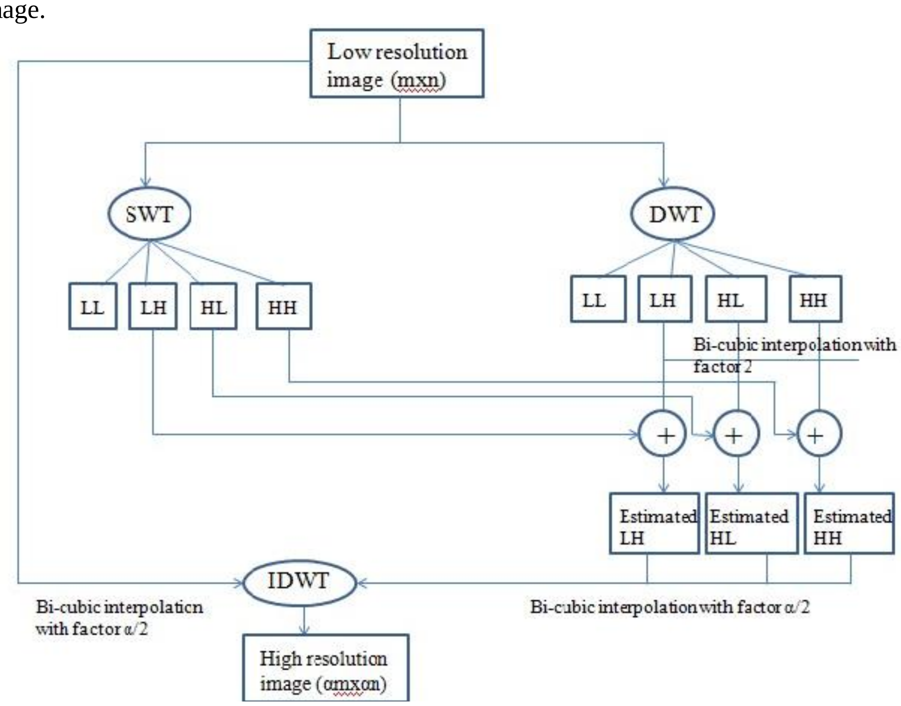

Fig 4. Block diagram of SWT with DWT based enhancement method

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E. Dual Tree Complex Wavelet Transform

DT-CWT based technique of image enhancement is one of the recent approaches which are used in image processing. DT-CWT is an improved technique of DWT because it improves the poor directionality of DWT. By using directional selectivity of CWT resolution enhancement can also achieved. The sharpness of edges can be improved by contribution of high frequency subband in 6 different directions. DT-CWT of an image gives 2 low frequency complex valued images and 6 high frequency complex valued images. The 6 high frequency subband images are obtained as a result of directional selective filters. The orientation of high frequency subband images are in different directions i.e $\{-15^{\circ},-45^{\circ},-75^{\circ}, +15^{\circ}, +45^{\circ}, +75^{\circ}\}$. Interpolation has been applied to the high frequency subband images with a factor of α/2 which gives interpolated high frequency subband images. The input low resolution image has been also interpolated with a factor of α. Inverse DT-CWT uses interpolated low resolution input image and interpolated high frequency subband images. The output of IDT-CWT gives high resolution output images. DT-CWT technique provides high directional selectivity, limited redundancy, shift invariant property and efficient computation. But the design of complex wavelets with perfect reconstruction properties and with good filter characteristics is difficult. DT-CWT preserves more high frequency information, reduces artifacts but it is not suitable for hyper spectral images.

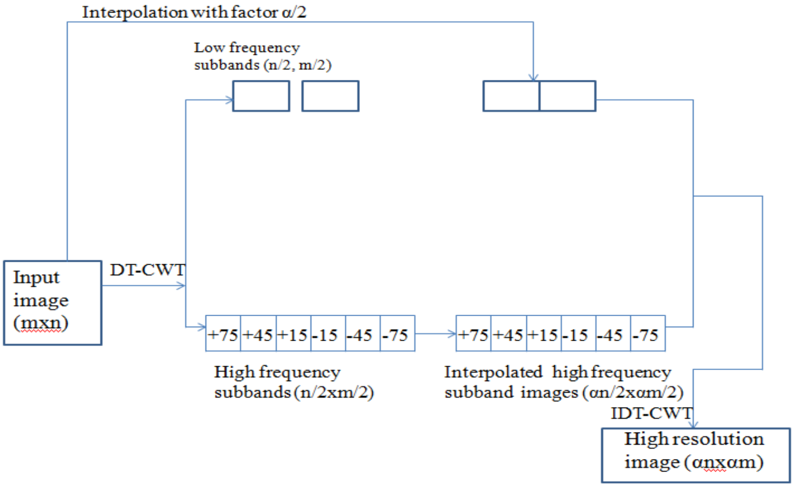

Fig 5. Block diagram of DT-CWT based enhancement method

F. Dual Tree Complex Wavelet Transform with Cycle Spinning

In this technique DT-CWT has been applied on the input low resolution image to obtain high resolution image. To generate N different shifting images, spatial shifting has been used along with horizontal and vertical directions. Where X and Y denotes number of horizontal and vertical line shift. N is (2n+1) * (2n+1) and X and Y € {-n, -n+1,… n-1, n}. After than wavelet transform has been applied and high frequency subband images are discarded to generate N low resolution images. Inverse spatial shifting has been applied and after image averaging operation on the resultant images we obtain the high resolution image.

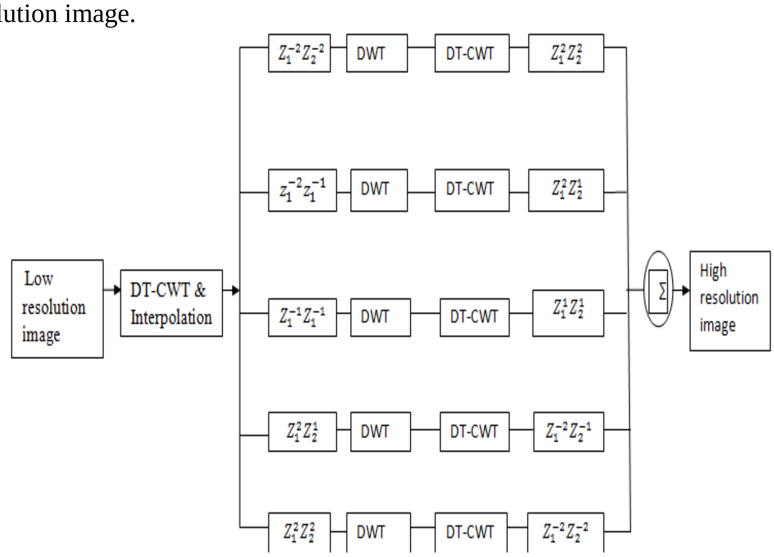

Fig 6. Block diagram of DT-CWT with CS based enhancement method

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III. EVALUTOIN METHODS

The result of all the techniques can be evaluated and compared in terms of PSNR (Peak signal to noise ratio), Mean and Standard deviation.

1. PSNR(in dB): can be obtained by using following formula,

$$\mathrm{PSNR} = 10\log_{10}\frac{(R^2)}{\mathrm{MSE}}$$

Where R is the maximum fluctuation in the input image.

2. Mean (M): Mean is given by average of pixel values. Mean is also required to calculate standard deviation which gives the quality measure for contrast enhancement of an image. Mean is given as

$$\mathrm{MSE} = \frac{\sum_{i,j}(I_{in\,(i,j)} - I_{org\,(i,j)})^2}{MXN}$$

3. Standard deviation (S): It is calculated using mean value. The deviation of pixel from its mean value is given by standard deviation. It tells about the spread between pixels. Contrast enhancement has been checked by the spreading between the pixels.

$$S = \sqrt{\frac{\sum(X-M)^2}{N-1}}$$

The various satellite image enhancement techniques has been tested on well-known benchmark images, which are images taken from satellite (a) Kutztown University, (b) Texas Reliant Stadium (c) Mississippi River.

Comparison of PSNR for the existing methods:

Table: 1

Image Resolution Enhancement Techniques	Kutztown University (a)	Texas Reliant Stadium (b)	Mississippi River (c)
DWT	19.3143	17.0715	22.2286
CWT	16.8078	15.3519	20.9604
DWT & SWT	14.2939	12.1483	11.5049
DASR	14.65551	11.9741	11.505
DT-CWT	17.0586	15.738	21.119
DT-CWT with CS	21.9554	19.016	21.442

IV. CONCLUSION

This paper compares various Satellite image enhancement techniques which are based on Wavelet Transform and Interpolation. All the technique uses wavelet based resolution enhancement. The analytical results of benchmark images after resolution enhancement shows that DT-CWT with cycle spinning method provides enhanced high resolution output image compare to other methods and it also provides de-noised image because of cycle spinning.

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