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Survey on Image Resolution Techniques for Satellite Images

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***Abstract*—Due to the low frequency nature of satellite image, it may appeared as blurred image. To improve the frequency of those images, image Resolution techniques are used. This is used in a huge number of applications such as remote sensing, medical imaging with important challenges such as reduction of aliasing, ringing, distortions, blurring, artifacts, etc. Enhancing the resolution of an image includes improving the number of pixels available to represent the details of image. This paper analyses the performance of various image resolution techniques for satellite images. The techniques are compared based on Mean Squared Error and Peak Signal to Noise Ratio.**

***Keywords* —Image Resolution, Discrete Wavelet Transform, Remote sensing, Multi wavelet Transform, Interpolation.**

I. INTRODUCTION

Enhancing the Resolution of an image is most important in the field of image processing. A common Resolution Enhancement (RE) technique is to vary the size of dots like pixels. Image resolution is the detail an image holds. Higher resolution means that more image detail. Image enhancement is one of the preprocessing techniques. The preprocessing is used to condition the image before going for processing [12]. Enhancement is used for particular application to obtain clear image that is much suitable than original image. Image processing is the processing of an image and it takes one image as an input and produces image as an output. This includes Image Enhancement, Image Segmentation, Image Compression, Noise Removal, etc. The Resolution Enhancement have classified as,

Pixel Resolution : When the pixel counts are referred to as resolution, the convention is to describe the pixel resolution with the set of two positive integers:1)Number of pixel columns(width), 2)Number of pixel rows(height).

Spatial Resolution : It is the measure of how lines are closely resolved in an image. In remote sensing, it is typically limited by diffraction, imperfect focus, etc.

Spectral Resolution : Color images distinguish light of different spectra. Multi spectral images resolve even finer differences of spectrum or wavelength than is needed to reproduce color.

Temporal Resolution : Movie cameras and high speed cameras can resolve events at different points in time. The time resolution used for movies is usually 24 to 48 frames/sec.

Radiometric Resolution : It determines how finely a system can represent or distinguish differences of intensity and usually expressed as number of levels or number of bits.

II. IMAGE RESOLUTION TECHNIQUES

A. Discrete Wavelet Transform (DWT)

A Discrete Wavelet Transform is any wavelet transform which uses wavelet coefficients. The DWT technique which captures both frequency and location information of an image. Resolution is an important feature in satellite imaging. The satellite image have high frequency contents as well as low frequency contents. And the image may have losing of high frequency contents. So, the DWT technique has been employed for resolution to preserve the high frequency components of the satellite images [10]. The process is to divide the satellite input image into four sub bands. They are Low-Low(LL), Low-High(LH), High-Low(HL), High-High(HH). Then the high frequency sub bands are estimated. The high frequency sub band images and the low resolution input images are interpolated and using inverse DWT we can get a resolution enhanced image [4]. The interpolation process is used to preserve high frequency contents of the image. The DWT technique is mainly used to produce the sharper enhanced image.

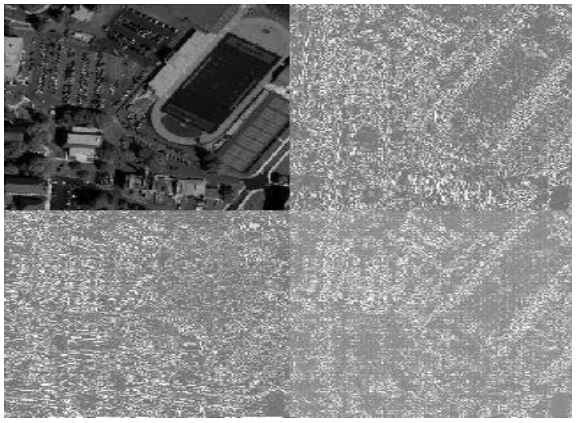


Fig.1 LL, LH, HL, and HH subbands of a satellite image obtained by DWT

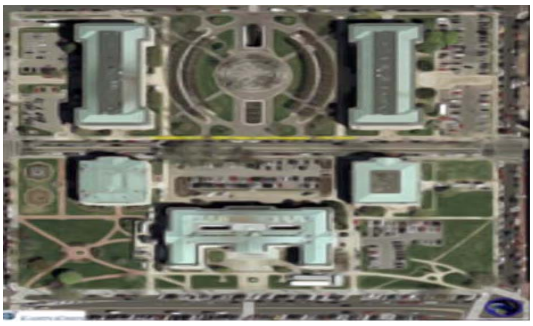
B. Stationary Wavelet Transform (SWT)

The Stationary Wavelet Transform is used to overcome the lack of translation-variance of the Discrete Wavelet Transform (DWT). And SWT technique is redundant. As like DWT, the SWT also divides the input image into different sub bands. The high frequency sub bands obtained by DWT and SWT are added with each other which mean they have the same size [13]. That is, the interpolated high frequency sub band coefficients have been corrected by the SWT high frequency sub band coefficients [5]. After that, the images are combined using inverse process to get resolution enhanced image. So, the technique generates a super resolved image.

C. Vector-Valued Image Regularization with Partial Differential Equations (VVIR-PDE)

In order to control the local smoothing behavior of image, this technique is used. The vector edges which have high vector variants to preserve the image information while removing the noise. So, the VVIR-PDE technique is used for image denoising. This VVIR-PDE technique mainly uses anisotropic smoothing to preserve the global features of vector images. This technique follows desired local geometric properties [15]. It is used in wide range of applications such as color image restoration to remove the noise, color image inpainting to remove the text in an image, color image magnification to remove bloc effects of an image, etc.

(a)



(b)

Fig.2 (a) Input Image (b) Output Image for VVIR-PDE

D. Adjacent Pixel Algorithm (APA)

This algorithm is used to produce sharper and clear images. The process which considers the pixel values for resolution. It is the method to increase the number of pixels in satellite images. So, the input image is divided into sub bands. Then, the pixel values are calculated. The Low-Low (LL) sub band which have low pixel values. An extra column is added to LL sub band and we have to assign the average pixel value of the neighboring pixels [8]. So, the pixel values are increased in LL sub bands. Then, the image gets clearer. As the pixel value increases, the images will get sharper and clearer.

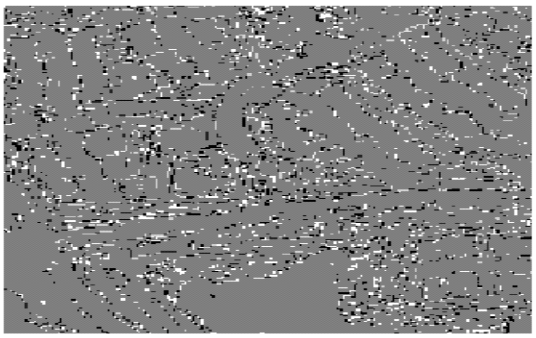


Fig.3 (a) the classification map for level 0 and level 1 image with mismatched pixels.

(b) the variation map based on the variance of the image at level 1.

E. Inter Sub band Correlation Technique (ISC)

This method which uses same phase for the sub bands. So, the sampling phase is considered. The method has the filter bank to estimate the sub bands [11]. The sub bands have correlation that is between low frequency band and high frequency band. If we have different phases, the sub bands will have low correlation with one another.

This method has three steps. They are,

1) First apply the wavelet transform to all different phases of each sub band.

2) The filters are used to estimate the bands in higher level.

3) Inverse wavelet transform is applied to enhance the resolution of an input image.

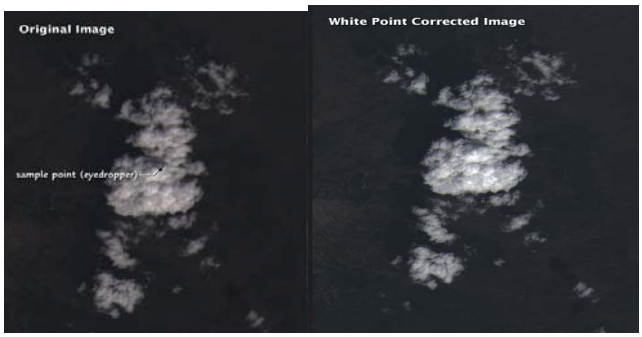
Thus, using the same phase for estimating the sub bands, this method will produce a time consuming process.

F. Singular Value Decomposition (SVD) Transform

This transform is used to enhance the satellite images. And it is used to improve the brightness of an image. Using DWT technique the image is divided into sub bands. The LL sub bands are obtained from the input image [6]. And

the singular value matrix is estimated for the Low-Low sub band image. Then the inverse DWT technique is applied to enhance the brightness of an image.

The SVD transform gives the better brightness when combined with DWT [3].



(a) (b)

Fig.4 (a) Input Image (b) Output image for SVD

G. Hybrid Directional Lifting (HDL) Technique

This HDL technique also used for image denoising process. Image denoising is carried out through three important steps [14]. They are,

1) The pixels are classified in texture and smooth regions of an image.

2) Then the pixels are estimated in smooth region for modifying the direction of each pixel.

3) Finally, the hybrid transform is used to reduce the noise in regions.

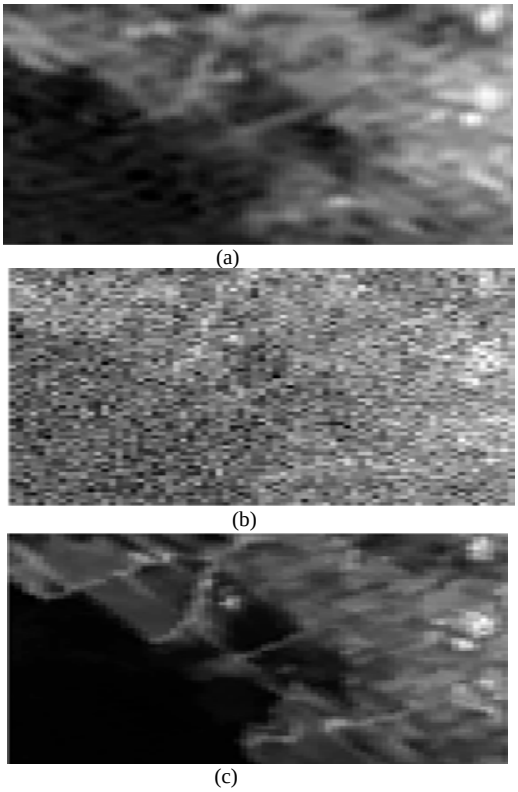
The HDL technique is used to improve the performance and denoise the image.

H. Dual-Tree Complex Wavelet Transform (DT_CWT)

In order to reduce the artifacts, the DT-CWT technique is used for satellite images [7]. It is also used in terms of reduction of aliasing that is distortion to the image, ringing that is unwanted oscillation of a signal presented in an image. The frequency of an image may not be continuous due to shift variant property. So, the property keeps on changing. The DT-CWT technique is used to overcome the shift variant property [9]. That is, Shift invariant. And also directionally selective.

The process includes,

1) Divide the Low Resolution (LR) input image into different sub bands.
2) The sub bands separated into coefficient and wavelet coefficient sub bands.
3) The wavelet coefficient sub bands and low resolution input image are interpolated.
4) Then, the high frequency sub bands are passed through filters to reduce the noise.
5) The filtered high frequency sub bands and low resolution image are combined using inverse DT-CWT to produce a high resolution image.



(a)

(b)

(c)

Fig.5 (a) Input Image (b) Noise present in input image (c) Ouput Image

Thus, the DT-CWT technique is nearly shift invariant and generates less artifacts.

III. PERFORMANCE ANALYSIS

In this section the performance of various image resolution techniques have been specified in the below Table I using MATLAB.

TABLE I
COMPARISON OF IMAGE RESOLUTION TECHNIQUES

Resolution Techniques	Advantage/ Disadvantage	Mean Squared Error (MSE)	Peak Signal To Noise Ratio (PSNR)
DWT	Gives Sharper image / Loses high frequency contents.	0.0419	13.7804
SWT	Redundant / Disortion may occur to the image.	0.0464	13.3332
VVIR-PDE	Removes the noise / Loses edge information.	0.0268	15.6780
APA	Gives clear view of an image / Loses linear features.	0.0376	14.0722
ISC	Less computational complexity / Sometimes have low correlation.	0.02934	15.2687
SVD	Improves the brightness of an image / Cannot give clear image.	0.0402	13.9634
HDL	Denoise the image / Unwanted oscillation of signal leads to error.	0.0472	14.4628
DT-CWT	Reduces Artifacts / Not much suitable for hyper spectral images.	0.0243	16.1566

IV. CONCLUSION

This paper analyses the performance of various resoluion techniques. Resolution Enhancement (RE) schemes, which are not based on wavelets have the drawback of losing high-frequency contents, which results in blurring. The Transforms and techniques are evaluated using MATLAB tool and given the performance shown in TABLE I. Some techniques have shift variant property. Although the DT-CWT and ISC techniques are almost shift invariant, and yields better performance, after the interpolation of wavelet coefficients. In Future, the Multi Wavelet Transform can be used to produce less artifacts when compared to other techniques for hyper spectral satellite images. It also enhance the performance of an satellite image in terms of MSE and PSNR.

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