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A Study on Satellite Image Resolution Enhancement Techniques

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***Abstract* - Satellite images are having vital role today. They are being used in several fields of research. A major issue of these kinds of images is their resolution. Resolution of an image refers to the sharpness of image detail, smootheness of curved lines and the faithful reproduction of that particular image. Satellite image may appeared as blurred image due to its low frequency nature. In order to improve the frequency of these images , resolution enhancement techniques are used .This paper is a comprehensive study of the various resolution enhancement techniques in the wavelet domain.**

***Index Terms* - Cycle Spinning (CS), Discrete Wavelet Transform (DWT), Dual Tree-Complex Wavelet Transforms (DT-CWT), High Resolution (HR), Low Resolution (LR), Wavelet Zero Padding (WZP)**

I. INTRODUCTION

Nowadays satellite images are being used in several applications such as meteorology, agriculture, geology, forestry, landscape, biodiversity conservation, regional planning, education, intelligence and warfare. Satellite images are affected by various factors such as absorption, scattering etc in the space.So the resolution of these images is very low. To have better perception of these images it is necessary to have the image with clear and well defined edges, which provides better visible line of separation etc.

Enhancing the resolution of an image is most important in the field of image processing. Enhancing the resolution of an image includes improving the number of pixels available to represent the details of image. A common Resolution Enhancement (RE) technique is to vary the size of dots like pixels. Image resolution means 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.

Resolution enhancement of these images has always been a major issue to extract more information from them. There are many approaches that can be used to enhance the resolution of a satellite image. Wavelet domain based methods have proved themselves as most efficient technique serving for the required purpose. Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. Resolution enhancement is classified into several types such as pixel resolution, spatial resolution, spectral resolution, temporal resolution etc.

One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been widely used in several image processing applications such as multiple description coding , facial reconstruction , and super resolution . There are three well known interpolation techniques, namely nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation. Image resolution enhancement in the wavelet domain is a relatively new research topic and recently many new algorithms have been proposed.

II. OVERVIEW OF RESOLUTION ENHANCEMENT TECHNIQUES

Wavelet Zero Padding

Wavelet Zero Padding in [1] is one of the simplest methods for image resolution enhancement. It assumes that the signal is zero outside the original support. The most common form of zero padding is to append a string of zero-valued samples to the end of sometime- domain sequence.Zero padding is used in spectral analysis with transforms to improve the accuracy of the reported amplitudes, not to increase frequency resolution. Without zero- padding, input frequencies will be attenuated in the output. Zero padding in the time domain is equivalent to optimal interpolation in the frequency domain, which restores the correct amplitudes. Since the wavelet transform is defined for infinite length signals, finite length signals are extended before they can be transformed. One of the common extension methods is zero padding.

Zero padding shifts the intersample spacing in frequency of the array that represents the result. In image resolution enhancement, wavelet transform of a low resolution (LR) image is taken and zero matrices are embedded into the transformed image, by discarding high frequency sub bands through the inverse wavelet transform and thus high resolution (HR) image is obtained.

In this method, wavelet transform of a LR image is taken and zero matrices are embedded into the transformed image, by discarding high frequency subbands through the inverse wavelet transform and thus HR image is obtained.[2]

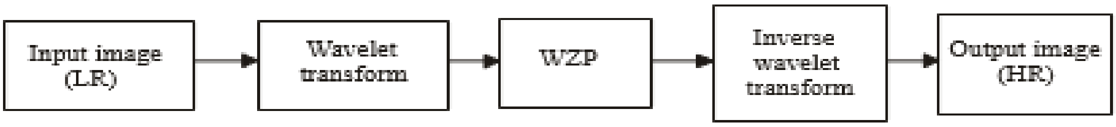

Figure 1: WZP[2]

Cycle Spinning

In Cycle Spnning[2] method, we follow the following steps to get highly resolved image.

First we obtain an intermediate HR image through WZP method. After that we obtain N number of images through spatial shifting, wavelet transforming and discarding the high frequency component. Again, the WZP process is applied to all LR images to obtain a number of HR images. These HR images are realigned and averaged to give a final HR image.

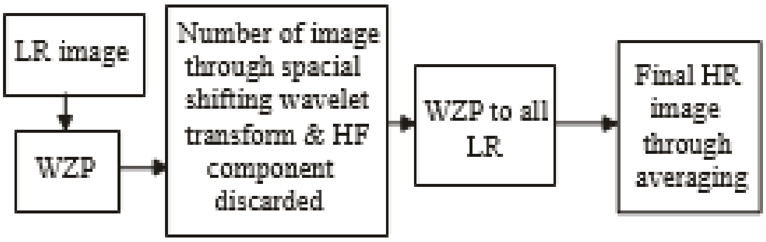

Figure 2: CS [2].

DWT

Discrete wavelet transform (DWT) is one of the recent wavelet transforms used in image processing .Wavelets are also playing a significant role in many image-processing applications. The 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform (DWT) along the rows of the image first, and then the results are decomposed along 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 those sub bands cover the full frequency spectrum of the original image.[3]

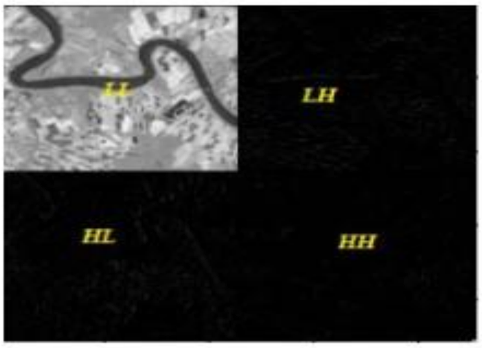

Figure 3: DWT[3]

Discrete wavelet transform based technique is most widely used technique for performing image interpolation. Here DWT is used to decompose a low resolution image into 4 subband images LL, LH, HL and HH. All the obtained low and high-frequency components of image are then interpolated. A difference image is obtained by subtracting the interpolated LL image from the original LR image. This difference image is then added to the interpolated high frequency components to obtain estimated form of HF subband images. Finally IDWT is used to combine these estimated images along with the input image to obtain high resolution images[2].

DT-CWT

The Dual Tree- Complex Wavelet Transform [4] is a relatively recent enhancement to the discrete wavelet transform (DWT), with important additional properties: It is nearly shift invariant and directionally selective in two and higher dimensions. It achieves this with a redundancy factor which is substantially lower than the undecimated DWT.

It is also an efficient technique to obtain a high resolution image. Block diagram for implementation of the method is shown in the figure 4. DT-CWT is applied to decompose an input image into different subband images. In this technique, direction selective filters are used to generate high- frequency subband images, where filters show peak magnitude responses in the presence of image features oriented at angle +75, +45, +15, -15, -45 and -75 degrees, respectively. Then the six complex- valued images are interpolated. The two up scaled images are generated by interpolating the low resolution original input image and the shifted version of the input image in horizontal and vertical directions. These two real valued images are used as the real and imaginary components of the interpolated complex LL image, respectively, for the IDT-CWT operation. Finally IDT-CWT is used to combine all these images to produce resolution enhanced image.[2]

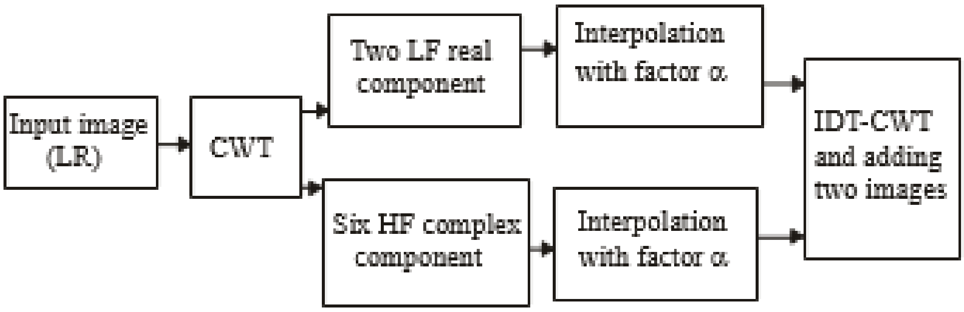

Figure 4: DT-CWT[2]

In order to reduce the artifacts, the DT-CWT technique is used for satellite images .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. That is, Shift invariant. And also directionally selective.

The process includes,

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

Thus, the DT-CWT technique is nearly shift invariant and generates less artifacts[4].

III. Studies and Findings

Performance analysis of various resolution enhancement algorithms in wavelet domain is done and measured in terms of metrics such as PSNR, MSE and ENTROPY.

Table 1: MSE, RMSE, PSNR and ENTROPY results for different techniques for figure 5[2]

Methods	MSE	RMSE	PSNR (db)	ENTROPY
WZP	0.0467	0.2161	32.2722	3.4598
CS	0.0706	0.2658	27.4267	2.7994
UWT	0.0675	0.2597	28.6002	3.5780
DWT/BILINEAR	0.0387	0.1966	32.8275	5.9913
DWT/NEAREST NEIGHBOUR	0.0342	0.1849	34.0733	5.7438
DWT/BICUBIC	0.0825	0.2872	26.6816	2.9862
DT-CWT/BILINEAR	0.0639	0.2528	28.4883	0.3602
DT-CWT/NEAREST NEIGHBOUR	0.0635	0.2520	28.7384	0.4812
DT-CWT/BICUBIC	0.0636	0.2523	28.7209	0.4297

As we can see from the table PSNR value for the different methods are around 30 db and ENTROPY values are varying one.

Table 1: MSE, RMSE, PSNR and ENTROPY results for different techniques after histogram equalization for figure 5[2]

Method	MSE	RMSE	PSNR (db)	ENTROPY
WZP	0.0426	0.2063	33.0103	4.7757
CS	0.0445	0.2110	31.9737	4.9216
UWT	0.0551	0.2347	30.9953	3.4475
DWT/BICUBIC	0.0729	0.2699	27.7575	5.8049
DT-CWT/BICUBIC	0.0406	0.2016	32.6450	6.5894

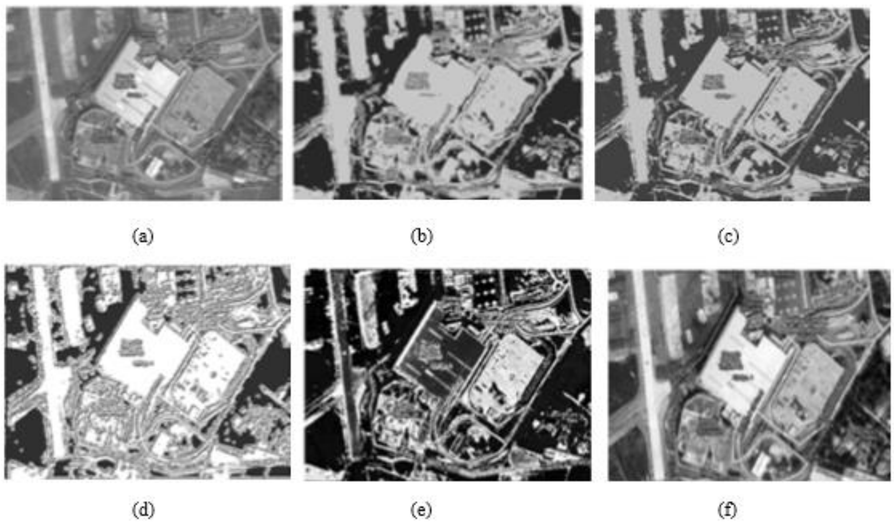

figure 5: (a) Original LR image (b) WZP (c) CS (d) UWT (e) DWT (f) DT-CWT[2]

IV. CONCLUSION

Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. Based on the above results DT-CWT is the most efficient method for satellite image resolution enhancement. High performance of DT-CWT is due to shift invariance and directional selectivity.

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