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A Comparative Review of Satellite Image Super resolution techniques

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Abstract – *Resolution of satellite images is a very important factor and needs to be preserved for various applications. A number of techniques have been proposed by various researchers in this context. Image resolution can be enhanced in frequency and spatial domains. This paper presents a comparative review of some of the common methodologies in frequency domain, that are used for satellite image resolution enhancement.*

Key Words: wavelet, transform, interpolation, DWT, bilinear, bicubic, WZP, cycle-spinning.

1. INTRODUCTION

Satellite imaging is carried out by a high flying satellite or aircraft that examines the earth to obtain knowledge about the earth. There are a number of satellites that examine the earth for different purposes. Satellite images are used in plenty of applications such as medical images, agricultural images, assisting planners and engineers, extracting mineral deposits, disaster mitigation planning and recovery. But, the images captured by satellites suffer from a number of artifacts due to very low frequencies. Hence in order to upgrade the quality of images, there are a number of image resolution enhancement methodologies designed and implemented by different researchers. This paper represents a study and comparison of different image resolution enhancement strategies. The image resolution enhancement methodologies can be classified into two broad categories:

1.1 Frequency Domain methods

Frequency domain strategies work upon the Fourier transform of the image. Fourier transform is computed for the original image, all the processing operations are carried out on this transform and then after all the operations, the inverse of transform is applied to obtain a high resolution image [6].

1.2 Spatial Domain Methods

Spatial domain images directly work upon the pixels of the input images. The operations are directly carried on the pixel values of the input image and finally a higher resolution image is attained. But these techniques are not robust as compared to frequency domain [10].

Image resolution enhancement in frequency domain is better as compared to spatial domain methods in all respects. Frequency domain methods make use of Fourier transforms and a technique called interpolation in order to enhance the resolution of the image. There are a number of interpolation techniques that can be used to interject new pixels into an image to enhance its quality [1][16].

2. Interpolation Based Frequency Domain Methods

Generally, interpolation is a technique that generates new pixel points on the basis of the existing pixel values. Interpolation is used in conjunction with different transforms in order to upgrade the resolution of satellite images. There are different types of interpolation techniques that are used in frequency domain [15].

2.1 Piecewise Linear Transformation: In this methodology, each and every pixel point is considered for manipulation. This enhances the resolution of an image by considering mean dynamic range maximization. It was first developed for monochrome images and then extended for color images [11].

2.2 Nearest Neighbor Interpolation (NNI): This is the simplest form of interpolation that does not actually produce a new pixel. NNI works by setting an empty pixel value inside the image to a new value corresponding to the value of the nearest pixel, that's why the name nearest neighbor. This results in enlargement of image pixels which causes some irregularity in the edges of the images [7][8]. Thus NNI is the least preferred technique for image resolution enhancement.

2.3 Bilinear Interpolation: The issue of irregularity in edges caused by nearest neighbor technique is solved by bilinear interpolation. Bilinear interpolation considers four diagonally nearest pixel values from the given pixel in order to determine the relevant intensity of that pixel [12]. First of all, 2X2 neighborhood of the unknown pixel is determined, and then a weighted average of these is carried out in order to find the appropriate value. This technique smoothens the edges of the image but may cause a little blurriness in the output image.

2.4 Bicubic Interpolation: In order to resolve the issues of nearest neighbor interpolation and bilinear interpolation, bicubic interpolation was designed. This strategy considers the 4X4 neighborhood of the unknown pixel, taking into account sixteen nearest pixels to determine the appropriate pixel value of unknown point. As the range is wider, thus bicubic interpolation produces better results as compared to nearest neighbor and bilinear interpolations.

2.5 2D Wavelet Transformation: Wavelet transformation is used to disintegrate the original image into a number of subband images with different frequencies. Discrete wavelet transform in two dimensions produces four subbands namely: : LL(low-low), LH(low-high), HL(high-low), and HH(high-high) subbands.The low-low subband is considered approximate to the original input image [9][14].

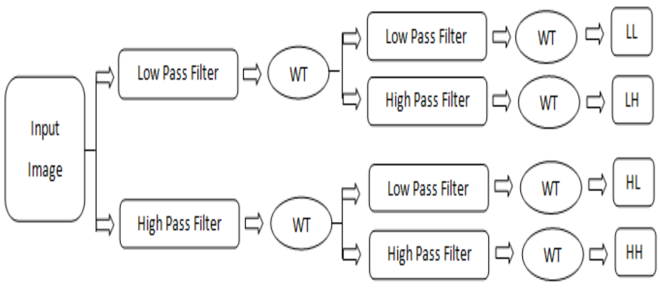

Fig -1: 2D Wavelet Transformation

2.6 2D Wavelet Transformation and WZP: To carry out the wavelet disintegration of an image, discrete wavelet transform in one dimension is applied along the rows and columns of the image. Out of the subbands produced, the low-low subband is used as the input image for further processing. After transformation, wavelet zero padding(WZP) is done. In WZP, matrices of zero are appended to the other three subband images and then, inverse of discrete wavelet transform is applied to obtain the output image [3]. WZP is a simple technique, but results are not much better as compared to those of bicubic interpolation.

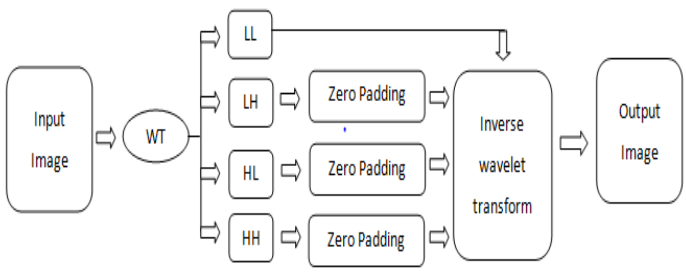

Fig -2: 2D Wavelet Transformation and WZP

2.7 2D Wavelet Transformation and CS: In this technique, first of all, an initial higher resolution image is originated using WZP, then cycle spinning(CS) is carried out where, a z-domain shift operator is applied on originated image in horizontal and vertical directions. CS produces a number of shifted images. After that, discrete wavelet transform is applied and all the higher resolution subbands are eliminated [13][16]. Finally, edge rectification is carried out to obtain the final output image.

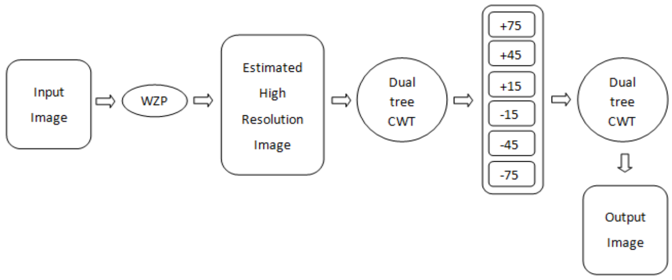

Fig -3: 2D Wavelet Transformation and CS

2.8 Complex WT: This technique is very similar to wavelet transformation. Likewise, complex wavelet transform produces two low frequency subbands and six high frequency subbands, that have complex values (real and imaginary parts). The higher frequency subbands are subjected to bicubic interpolation by factor of α and a factor of α/2 to attain a number of high frequency complex valued subbands [10]. Finally, all these subband images are subjected to inverse of CWT to produce the final high resolution output image.

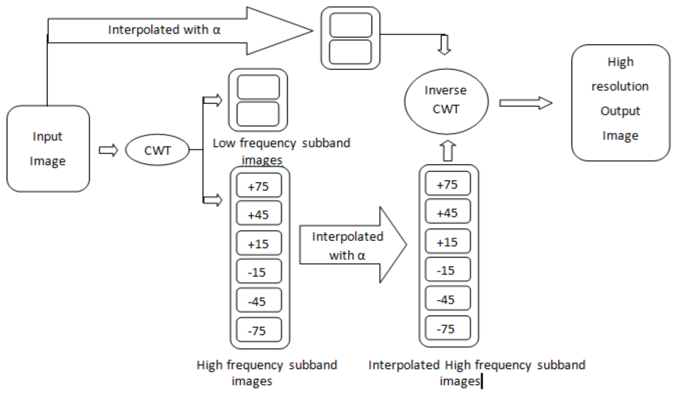

Fig -4 Complex WT

2.9 Discrete WT: This is a simple technique in which wavelet transform is first of all applied to the original image two produce the four subbands. Then, the higher frequency subbands are interpolated using bicubic interpolation which produces high resolution coefficients, which are then subjected to inverse of wavelet transform to attain the final output image [4][5][17].

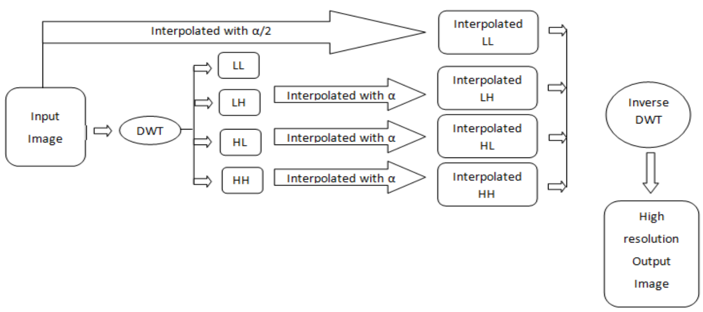

Fig -5 Discrete WT

3. CONCLUSIONS

The review and study of various image resolution enhancement techniques is done and it has been observed that interpolation alone cannot upgrade the resolution of the satellite images. Thus, wavelet transform in combination with interpolation is used. Out of the existing interpolations, bicubic interpolation is the best in terms of performance, and thus, it is used with wavelet transforms to enhance the image resolution [2][18].

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