Satellite Image (Multispectral) Enhancement Techniques in Wavelet Domain: An Overview

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ABSTRACT
Satellite images are used in many applications like military, forecasting, astronomy, and geographical information. Satellite images have to face spatial and spectral resolution problems due to scattering, atmospheric conditions, etc., also they have poor perception. This limitation of resolution needs to be overcome before further processing. The goal of image resolution enhancement is to improve specific features of an image for its correct representation. Better resolution is obtained by applying enhancement techniques on blurred and noisy images. In this paper various image enhancement techniques under wavelet domain like WZP, DWT, and DT-CWT are discussed. This paper also gives selection of suitable enhancement technique

Keywords
Satellite Image enhancement, Wavelet Transform, Remote sensing, Multispectral image enhancement, Interpolation.

1. INTRODUCTION
Satellite images are used in different areas such as monitoring the processes on the Earth's surface, detection of changes in atmosphere; measuring and estimating geographical, biological and physical parameters, etc. Resolution of these images is very important to obtain information from satellite images so it plays a major role in satellite image enhancement. Image Enhancement is a process of obtaining a high quality or high resolution image from low quality or low resolution satellite image, for further processing of an image, such as analysis, detection, segmentation and recognition [2]. It is an important step in image processing of satellite images.

Another important parameter related to resolution is that, spatial resolution of sensors is often limited with respect to their spectral resolution. Sensors provide information with higher level of spatial detail, but lack in spectral information [19]. Since the design of a high resolution sensor in both spectral and spatial domains would be extremely costly and challenging in terms of engineering, image enhancement methods are often employed to create an image taking advantage of both panchromatic and multi- or hyperspectral sensors [19]. Principal Component Analysis (PCA), Conical Correlation Analysis (CCA) methods are not efficient to obtain better results when applied to remote sensing images. Therefore for image processing specific approaches based on Laplacian Pyramids, wavelets, geostatistics, and Bayesian Maximum Entropy, have been proposed recently [1], [2], [19].

Transform theory plays important role in image processing. It can also give us more information about image [5]. Various kinds of transforms are used for the image enhancement such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT). One of the drawbacks of DFT is, if the full Fourier transform is applied to points, which are far apart, many higher Fourier components would be added to compensate for this. Fourier analysis might take more time to complete the task because it based on trial and error approach. Also the absence of local information in classical Fourier transform of a signal makes it inadequate in time frequency analysis of a signal [17]. Another problem of Fourier transform is that it does not provide solution in both time and frequency domains simultaneously. On the other hand outputs of DCT are not integer; it shows block effects in final result [18], therefore we cannot use it for lossless compression.

These problems can be solved by interpolating images in wavelet domain like Discrete wavelet transform can avoid the block effect caused by DCT, as it includes neighborhood information in final solution. It also has good localization and symmetric properties [18].

There are different purposes to capture images via satellite such as, to calculate or measure the area under water while flooding condition occurs [14], area of land which is used for farming, living and industrial purpose, to differentiate the usable land and unusable land, detection of ships, airplanes, cars etc., detection of new buildings in desired area, etc. There are different satellites used to capture images of earth or any other planet such as LANDSAT-8, FORMOSAT-2, IKONOS, Quick Bird, Rapid Eye, SPOT, Terra SAR-X & Tan DEM-X, COSMO-SkyMed, WorldView-1, WorldView-2, GeoEye-1.

In this paper some of image enhancement techniques in wavelet domain are discussed, like Cycle Spinning (CS), Discrete Wavelet Transform (DWT), Dual Tree-Complex Wavelet Transforms (DT-CWT), DWT- Stationary Wavelet Transform (DWT-SWT), Wavelet Zero Padding (WZP).

2. LITERATURE SURVEY
Recently numbers of techniques are used for increasing the quality of images in various applications. Each technique produces different artifacts and results. Hasan Demirel and Gholamreza Anbarjafari [3] proposed a DWT technique for interpolating the images. But the images obtained from DWT and IDWT technique is not sharp, it has low PSNR as compared to other methods. Hasan and Gholamreza [7] covered the Discrete and stationary wavelet decomposition technique based on interpolation of high frequency subband images resulting from DWT. In this technique high frequency components of image are enhanced by stationary wavelet transform. This technique produces comparatively greater results. Hasan Demirel and Gholamreza Anbarjafari [9] discussed Complex Wavelet Transform (CWT) which is used in image processing. CWT produces two complex-valued low-frequency subband images and six complex valued high-frequency subband images of original image. MSE and PSNR of the super resolved image is also improves in this method.

According to Robert G. Keys [10] Cubic convolution interpolation is derived from set of conditions. These sets are further applied to interpolation kernel. Interpolation kernels are design to maximize accuracy for given level of computation factor. Also storage and computing time required for cubic convolution is less than cubic splines. Yinji Piao, et.al. [12] discussed about inter-subband correlation in wavelet domain which uses correlation of subband with different sampling phases in DWT. In this enhancement technique sampling phase of DWT is taken into consideration. By analyzing correlation between lower level and higher level subbands, interpolation filters are designed. Initially filters are estimated by applying wavelet transform to low resolution image. Estimated filters are then used to estimate bands in higher level. Finally inverse wavelet transform is performed to enhance the resolution of input image.

3. THEORETICAL BACKGROUND

3.1 Wavelet Transform

Fourier transform is a powerful tool that has been available for signal analysis from many years. It gives information regarding the frequency content of a signal [1]. However, the problem with using Fourier transform is that, frequency analysis cannot offer both-good frequency and time resolution at the same time. Fourier transform does not give information about the time at which a particular frequency has occurred in the signal. Hence, a Fourier transform is not an effective tool to analyze a non-stationary signal.

Wavelet transform (WT) represents an image as a sum of wavelet functions (wavelets) with different locations and scales [18]. Wavelet is a solution [2] to multi-resolution problem and also it provide flexibility to represent non-stationary image signals. A wavelet has an important property of not having a sampling window of fixed width. WT is an efficient tool to represent an image.

Wavelet Transform can be classified in to two categories, (i) Continuous Wavelet Transforms (CWT), and (ii) Discrete Wavelet Transforms (DWT). For long signals, continuous wavelet transform can be time consuming since it needs to integrate overall times [3]. To overcome the time complexity, DWT was introduced. DWT can be implemented through sub band coding. The DWT is useful in image processing because it can simultaneously localize signals in time and scale, whereas the CWT can localize signals only in the frequency domain.

3.2 Classification of Enhancement Method

Image enhancement of low resolution images is a challenging task due to low contrast, un-visual characteristic features of an image. Basically there are two types of resolution enhancement methods: Spatial Domain and Spectral Domain

Spatial domain based image enhancement operates directly on pixels. Spatial based domain technique is conceptually simple to understand and the complexity of these techniques is low. But these techniques generally lacks in providing adequate robustness and imperceptibility requirements.

Spectral (frequency) based domain image enhancement operate directly on the transform coefficients of the image such as Fourier transform. Discrete wavelet transforms (DWT), and discrete cosine transform (DCT) techniques have low complexity of computations and easy applicability of special transformed domain properties. But it cannot simultaneously enhance all parts of image very well and it is also difficult to automate the image enhancement procedure.

3.3 Interpolation Technique Types

Interpolation is the process of estimating the values of a continuous function from discrete samples [1]-[5], [10]. Applications of interpolation in image processing include image magnification or reduction, sub pixel image registration to correct spatial distortions, and image decompression, etc. [8]. There are many image interpolation techniques available, nearest neighbor, bilinear and cubic convolution are the most common. The cubic convolution interpolation provides a perfect reconstruction of a continuous function [10].

Nearest neighbor interpolation algorithm is the most simple and fast algorithm, but it results in significant distortion. Bilinear interpolation method is more complex than the nearest neighbor method, so it has larger calculation. Bicubic interpolation algorithm can get relatively clear picture quality, but to obtain clear picture, it needs to do larger amount of calculation.

4. DIFFERENT SATELLITE IMAGE ENHANCEMENT TECHNIQUES

4.1 Wavelet Zero Padding (WZP)

Wavelet zero padding is one of the simplest methods for image resolution enhancement. Block diagram of this method is shown in Fig. 1. 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].

4.2 Cycle Spinning

In this method, following steps as shown in Fig.2 are used to get highly resolved image. First obtain an intermediate HR image using WZP method. After that obtain N number of images by using spatial shifting wavelet transforming and discarding the high frequency component. Wavelet Zero Padding process is again applied to all LR images to obtain number of HR images. Once obtain HR images, then realigned and averaged them to give a final HR image.

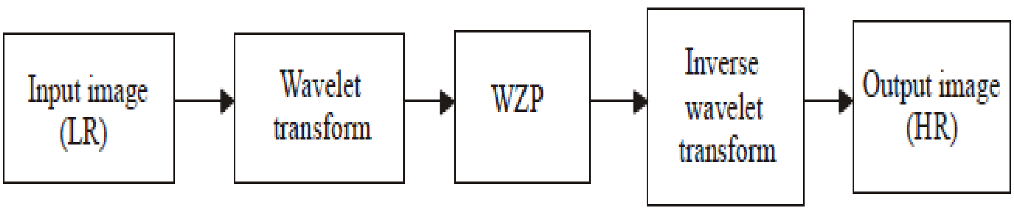

Fig. 1 Block diagram of Wavelet zero paddong method [2].

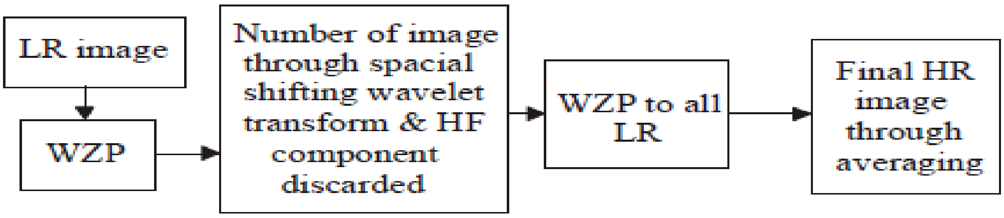

Fig. 2 Block diagram of Cycle Spinning [2].

4.3 WZP-CS Method

It is combination of WZP and CS technique [3]. Final high resolution image is obtained using two steps. Those steps are as follows:

1) An initial approximate, unknown high resolution image is generated using wavelet domain zero padding (WZP).

2) The cycle-spinning methodology applied to accomplish the following tasks:

a) Estimated high resolution images obtained in step 1 are used to generate number of low resolution images.

b) Wavelet zero padding method is again applied to all those low resolution images yielding N high resolution images.

c) These intermediated high resolution images are realigned and averaged to give the final high resolution reconstructed image.

Fig. 4 shows the block diagram of the WZP- and CS-based image super resolution.

4.4 Discrete Wavelet Transform (DWT)

Discrete Wavelet Transform (DWT) based technique is most widely used technique for performing image interpolation [3]. DWT use filter banks and special wavelet filters for the analysis for the reconstruction of the multi-resolution time-frequency plane [8]. Here DWT is used to decompose a low resolution image into 4 subband images LL, LH, HL and HH. All low and high-frequency components of image are then interpolated. Then a difference image is obtained by subtracting LL image from the original LR image. Resulting image is then added to the interpolated high frequency components to obtain estimated form of HF subband images. Finally IDWT used to combine these estimated images along with the input image to obtain high resolution images [3].

4.5 Dual tree-Complex WT (DT-CWT)

In this technique, dual-tree CWT (DT-CWT) [9], [13] is used to decompose an input image into different subband images. In this technique direction selective filters are used to generate high frequency sub-band images where filter show peak magnitude responses in the presence of image features oriented at angle +75, +45, +15, -15, -45 and -75 degrees, respectively [2]. Then six complex valued images are interpolated. Once interpolated, combine all images to generate a new high-resolution image by using inverse DT-CWT. Resolution is achieved [13] by using directional selectivity provided by the CWT, where the high-frequency subbands contribute to the sharpness of the high-frequency details. Finally IDT-CWT used to combine all these images to produce resolution enhanced image.

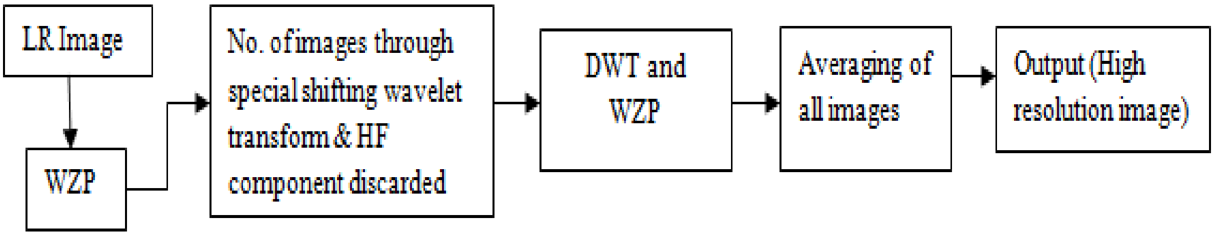

Fig. 3 Block diagram of WZP-CS method [3].

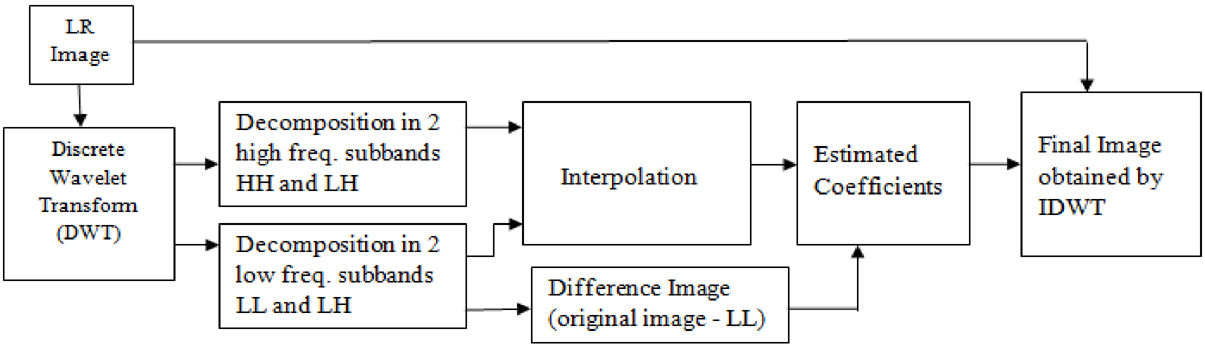

Fig. 4 Block diagram of DWT method.

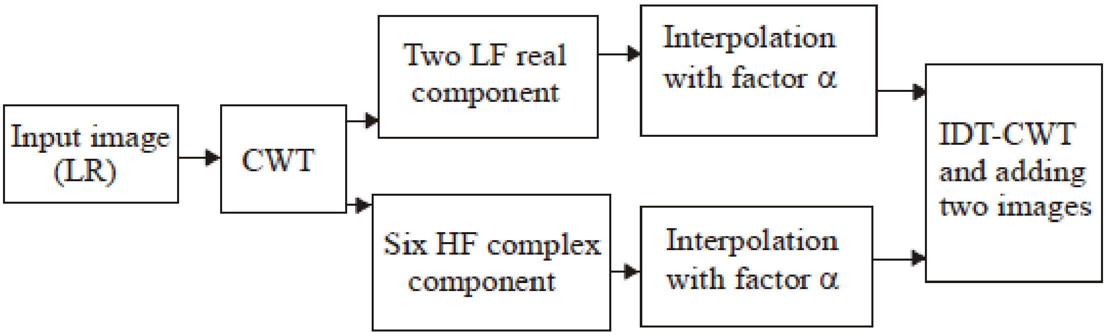

Fig. 5 Block diagram of DT-CWT method [2].

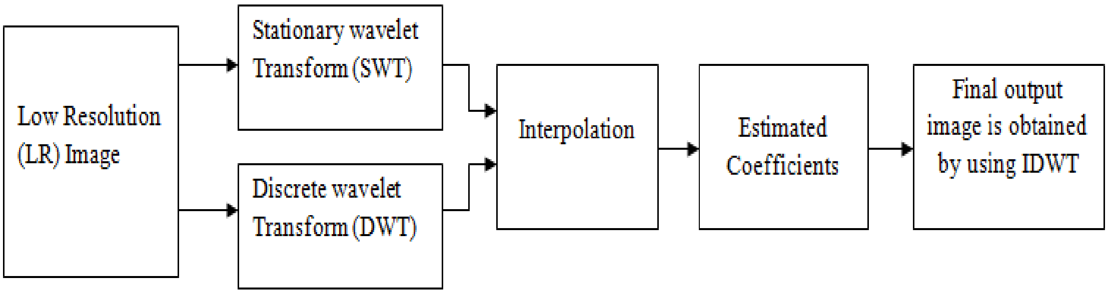

Fig.6 Block diagram of DWT-SWT method.

4.6 DWT-SWT

DWT-SWT stands for Discrete wavelet transform-Stationary wavelet transform. In this technique we are using DWT in order to preserve the high frequency components of the image (stationary wavelet transform uses high and low pass filters [8]). The DWT and SWT [7] are used to decompose the input image into different subbands. In this technique DWT is used in order to preserve the high frequency components of the image [8]. But because of DWT, information loss occurs due to the down sampling in each sub-band. Hence to minimize this loss SWT is employed. The SWT high frequency subbands and interpolated high frequency subbands have the same size hence that can be added with each other. After correlation new high frequency sub-bands are obtained. After interpolation inverse discrete wavelet transform (IDWT) is applied to all the interpolated subbands to obtain final High resolution image.

5. MATHEMATICAL PARAMETERS

To evaluate the performance of each algorithm different metrics such as Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE) has been calculated:

5.1 Mean Square Error (MSE):

Mean square error (MSE) is defined as an average of positive errors between original image and enhanced image. MSE should be as minimum as possible for better quality image.

5.2 Peak Signal to Noise Ratio (PSNR):

PSNR is most commonly used to measure the quality of reconstruction of lossy compression codecs. It also used to measure the ratio between maximum possible power of signal and power of corrupting noise that affects the fidelity of its representation. Generally higher PSNR represents that the construction is of higher quality, sometimes it may not.

5.3 Entropy:

Entropy is an average amount of information contained in each message received where message can be an event or sample, or character, or a data stream.

6. CONCLUSION

Satellite image resolution enhancement is the one of the important aspect for land use and land cover analysis in remote sensing. Due to limitations of sensors there is need of the resolution enhancement in the remote sensing. Selection of an appropriate algorithm is depending on image contents, viewing conditions, specific tasks, etc. Image Enhancement technique will reduce a cost to manufacture a sensor, because an algorithm will provide both spectral and spatial information of a satellite image. This paper gives brief idea about the different enhancement techniques. Wavelet Transform gives better results as compared to other methods. According to applications and input data most reliable transform is selected. Further improvement in techniques can be achieved by synthesizing the various filter banks and interpolation techniques.

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