ENHANCEMENT OF IMAGE RESOLUTION USING DTCWT AND ADAPTIVE BILATERAL FILTER

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Abstract: Resolution enhancement RE methods are not based on wavelets and it suffer from the disadvantage of losing high frequency content which results in blurring. The discrete wavelet-transform-based (DWT) RE scheme forms artifacts which are because of a DWT shift-variant property. The dual-tree complex wavelet transform (DT-CWT) and Adaptive Bilateral Filter (ABF) are based on a wavelet-domain approach and it proposed for satellite images of RE. DT-CWT is nearly shift invariant and it is decomposed from a satellite input image which is used to obtain high frequency sub-bands. Lanczos interpolator used for low-resolution input images and the high-frequency sub-bands interpolation and the high frequency sub-bands are approved through an ABF filter to provide for the artifacts generated by DT-CWT. The filtered high-frequency sub-bands as well as the LR input image are combined using inverse DT-CWT to get a resolution-enhanced image. Objective and subjective analyses make known the advantage of the planned technique over the conventional with state-of-the-art RE techniques.

***Index Terms* - Dual-tree complex wavelet transform (DT-CWT), Lanczos interpolation, resolution enhancement(RE), shift variant.**

I. INTRODUCTION

In the recent years there is increased in the demand for better quality images in the various applications such as medical, astronomy, object recognition. Satellite images are used in diverse areas such as monitoring the processes on the Earth's surface, discovery of changes in atmosphere; measuring as well as estimating geographical, biological and physical parameters, etc. The resolution of these images is extremely significant to obtain information from satellite images so it plays a main role in satellite image enhancement. And the Image Enhancement is a process of obtaining a high quality or high resolution image from low quality otherwise low resolution satellite image, for supplementary processing of an image, such as analysis, detection, segmentation along with recognition [2]. It is an essential step in image processing of satellite images. Image resolution enhancement is also widely useful for satellite image applications which contain bridge recognition, building construction in GPS technique. For image enhancement method there are two domains has been occupied into consideration one is image domain as well as transform domain. Transform domain conclude which transformations used in the enhancement. Image interpolation is usually used resolution enhancement scheme for different applications. Image interpolation is the process of using recognized data to approximation values at unknown locations. Interpolation method select new pixel from surrounding pixels. Mostly there are two types of interpolation algorithms.

1. Adaptive algorithm- This algorithm changes depending on what they are interpolating.

2. Non adaptive algorithms- contain linear interpolation algorithms.

Linear interpolation includes adjacent neighbor, bilinear, Bi-cubic interpolation. But images obtained by these linear interpolation technique produces numerous artifacts similar to blurring, blocking etc. To avoid these problems nonlinear interpolation algorithms are intended for resolution enhancement. Computational problem is increase as interpolating factor is increases. Transform domain decide which transformations used in the enhancement. Transform theory plays an essential role in image processing, as functioning among the transform of an image instead of the image itself may well give us additional insight into the properties of the image. Two dimensional transforms are applied to image enhancement, restoration, encoding also description. Various types of transforms are used for the image enhancement. DFT (Discrete Fourier Transform) having one drawback of DFT is that the transform works badly when the end points are far away apart. If the full Fourier transform was applied in this case, many higher Fourier components would be introduced to recompense for this. DCT (Discrete Cosine Transform) having one drawback is that there is no way to use the DCT for lossless compression, because outputs of the transform are not integers. This difficulty can be solved with interpolating images in wavelet domain. Instead of applying a block transform, one can attempt by a transform where one block influences numerous other (surrounding) blocks. This may reduce the so, artifact like blocking may be separated when using sub-band transforms. To create better result, it is effective to use wavelet transform. Wavelet transformation, initially a mathematical tool for signal processing, is now popular in the field of image fusion. Recently, numerous image fusion methods based on wavelet transformation have been published. The wavelets used in image fusion can be characterized into three common classes: Orthogonal, Biorthogonal and Non-orthogonal. Although these wavelets share several common properties, both wavelet leads to unique image decomposition and a reconstruction process which leads to differences between wavelet fusion methods. The wavelet transform has become a useful computational tool for a variety of signal as well as image processing applications. Although these wavelets share several common properties, both wavelet leads to unique image decomposition and a reconstruction process which leads to differences between wavelet fusion methods. The wavelet transform has become a useful computational tool for a variety of signal as well as image processing applications. Wavelet transforms are also useful for 'cleaning' signals as well as images (reducing unwanted noise along with blurring). Various algorithms for processing excessive images, for case, are based on wavelet as well as wavelet-like transforms. The wavelet transform of the image is primary computed, the wavelet illustration is then modified appropriately, and after that the wavelet transform is reversed (inverted) to get a new image. When constructing sub-band transforms as of wavelets, we will create the transform by first finding a filter bank as of the scaling function of the wavelet. Transforms in image processing are two dimensional, thus we require a little comment on how we implement a separable transform. When a two dimensional transform is divisible, we can calculate it by applying the equivalent one-dimensional transform to the columns first, furthermore then to the rows. Wavelet transform is used in different images processing application and produces better quality images. The remainder of this paper is organized as follows: Section 2 briefly discusses the previous work done on the DWT. Preliminaries in section 3. Proposed technique is described in Section 4. Section 5 given the mathematical parameter used in this proposed method. Section 6 reports results and discussion and at last conclusion of this proposed technique mentioned in Section 7.

II. PREVIOUS WORK

Resolution (spatial, spectral, and temporal) is the limiting factor for the utilization of remote sensing data (satellite imaging, etc.). In satellite images (unprocessed) Spatial and spectral resolutions are related (a high spatial resolution is associated with a low spectral resolution and vice versa) with each other [1]. So, spectral, as well as spatial, resolution enhancement (RE) is desirable. Interpolation has been widely used for RE [2], [3]. Commonly used interpolation techniques are based on nearest neighbors (include nearest neighbor, bilinear, bicubic, and Lanczos). The Lanczos interpolation (windowed form of a sinc filter) is superior than its counterparts (including nearest neighbor, bilinear, and bicubic) because it has increased ability to detect edges and linear features. And it also offers the best compromise in terms of reduction of aliasing, sharpness, and ringing [4]. Methods based on vector-valued image regularization with partial differential equations (VVIR-PDE) [5] and inpainting and zooming using sparse representations [6] are now state of the art in the field (mostly applied for image inpainting but can be also seen as interpolation). RE schemes (which are not based on wavelets) suffer from one major drawback of losing high frequency contents (which results in blurring). RE by using wavelet domain is a new research area, and recently, many algorithms [discrete wavelet transform (DWT) [7], stationary wavelet transform (SWT) [8], and dual-tree complex wavelet transform (DTCWT) [9] have been proposed [7]–[11]. An RE scheme was proposed in [9] using DT-CWT and bicubic interpolations, and results were compared (shown superior) with the conventional schemes (i.e., nearest neighbor, bilinear, and bicubic interpolations and wavelet zero padding). More recently, in [7], a scheme based on DWT and bicubic interpolation was proposed, and results were compared with the conventional schemes and the state-of-art schemes (wavelet zero padding and cyclic spinning [12] and DT-CWT [9]). But, DWT is shift variant, which causes artifacts in the RE image, and has a lack of directionality; so, DT-CWT is almost shift and rotation invariant [13]. DWT-based RE schemes generate artifacts (due to DWT shift-variant property). In this paper, a DT-CWT-based adaptive bilateral filter based RE (DT-CWT-ABF-RE) technique is proposed, using the DT-CWT, Lanczos interpolation, and ABF. This DTCWT technique is nearly shift invariant and directional selective. Moreover, DT-CWT preserved the usual properties of perfect reconstruction with well-balanced frequency responses [13], [14]. Consequentially, DT-CWT gives better results after the modification of the wavelet coefficients and provides less artifacts, as compared with traditional DWT. Since the Lanczos filter offer less aliasing, sharpness, and minimal ringing, so, this one is the better choice for RE. ABF filtering [15] is used to further enhance the performance of DT-CWT-ABF-RE by reducing the artifacts. The results (for spatial RE of optical images) are compared with the best performing techniques [5], [7] – [9].

III. PRELIMINARIES

A. Dual Tree Complex Wavelet Transform

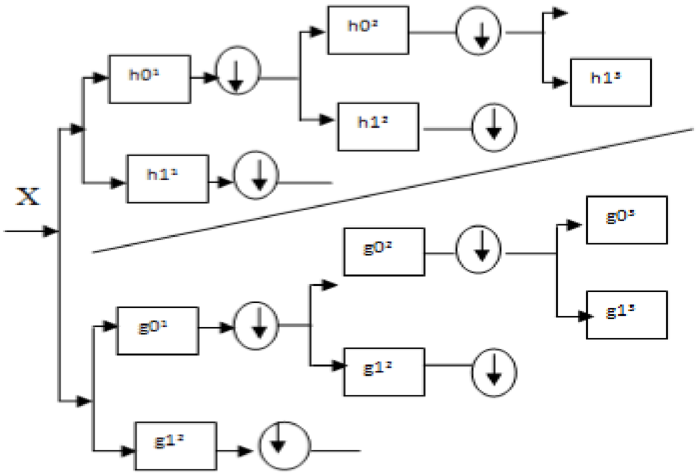

Figure 1: Dual Tree Complex Wavelet Transform

A complex wavelet transform is one solution with shift invariance and limited redundancy. Kingsbury introduced a more computationally efficient approach for a shift invariance transform, the Dual-Tree Complex Wavelet Transform (DT-CWT) that has the following properties [16]:

- Perfect reconstruction
- Approximate shift invariance
- Limited redundancy, independent of the number of levels

Two DWT filter bank are employed in the DT-CWT one gives the real part of the transform while the second DWT gives the imaginary part. The two real wavelet transforms use two different sets of filters. DTCWT transform is approximately analytic because the two sets of filters are jointly designed. In figure 1, x is input image, h0 and h1 is low and high pass filter pair for real part and go, and g1 is the low and high pass filter pair for imaginary part.

B. Adaptive Bilateral Filtering

The shift-variant filtering operation of the proposed ABF and its impulse response are shown in (1) and (2), respectively [17].

$$\hat{f}[m,n]=\sum_k \sum_l h[m,n;k,l]g[k,l], \quad (1)$$

Where $\hat{f}[m, n]$ is the restored image, h[m, n; k,l] is the response at [m, n] to an impulse at [k,l], and g[m, n] is the degraded image.

$$h[m,n;m_0n_0]=I(\Omega_{m0,n0})r^{-1}_{m0,n0}e^{-\left(\frac{(m-m_0)^2+(n-n_0)^2}{2\sigma_d^2}\right)}e^{-\frac{1}{2}\left(\frac{g[m,n]-g[m_0,n_0-\zeta[m_0,n_0]}{\sigma_r[m_0,n_0]}\right)^2} \quad (2)$$

where [m0, n0] is the center pixel of the window, Ωm0,n0 = {[m, n]:[m, n] ∈ [m0 − N,m0 + N]×[n0 − N,n0 + N]}, I(·) denotes the indicator function, and rm0,n0 normalizes the volume under the filter to unity. Compared with the conventional bilateral filter given in [3], ABF contains two important modifications: First, an offset ζ is introduced in the range filter. Second, both ζ and the width of the range filter σr in ABF are locally adaptive. If ζ = 0 and σr is fixed, ABF will degenerate into a conventional bilateral filter. For the domain filter, a fixed low pass Gaussian filter with σd = 1.0 is adopted in ABF. The combination of a locally adaptive ζ and σr transforms the bilateral filter into a much more powerful filter that is capable of both smoothing and sharpening. Moreover, it sharpens an image by increasing the slope of the edges.

IV. PROPOSED ALGORITHM

DT-CWT decomposes a low resolution input image into 12 high frequencies and 4 low frequencies sub-bands. Low frequency sub-band images are the low resolution of the original image. Therefore, instead of using DTCWT decomposed low-frequency sub-band images, which contain less information than the original input image, in proposed algorithm using the input image for the interpolation. Hence, the quality of the super resolved image increases by using the input image for interpolation, instead of the low frequency sub-band images. In proposed method the input image is interpolated by factor α/2 and by α to interpolate the high-frequency sub-bands by lanczos filter. The interpolated high frequency sub-bands pass through the adaptive bilateral filter to diminishing the remaining artifacts. By applying IDT-CWT, the resulting output image with the enhanced resolution of satellite images with preserving the edges. The output images contain sharper edges than the interpolated image obtained by interpolation of the input image directly. In summary, the proposed algorithm interpolates not only the input image but also the high-frequency sub-band images obtained by the DT-CWT process. The final high-resolution output image is generated by using the IDTCWT of the interpolated sub-band images and the input image. In the proposed technique, the employed interpolation method is the same for all sub-band and the input images.

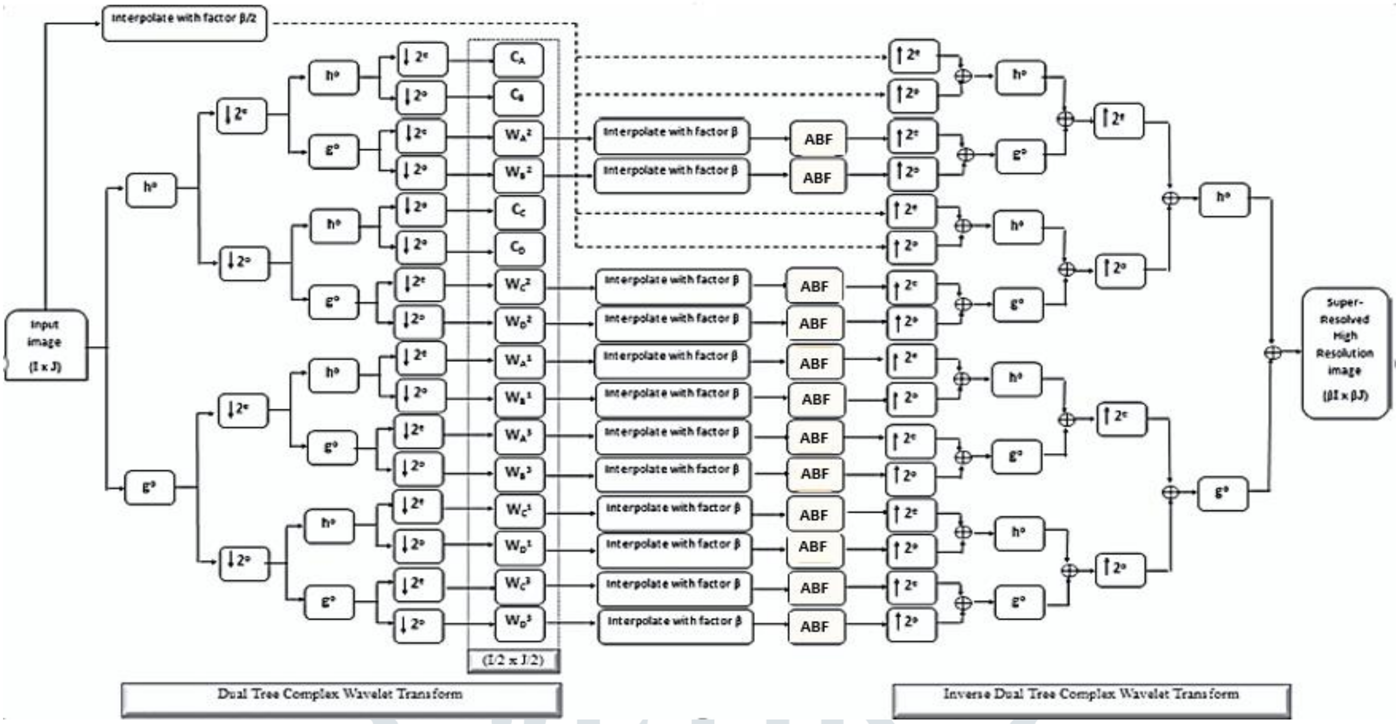

Figure 2: Block Diagram of the proposed algorithm DTCWT-ABF-RE.

V. MATHEMATICAL PARAMETERS

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

A. Mean Square Error (MSE):

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

$$MSE = \sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)^2}{n-2}$$

Where, yi is the estimated mean, $\hat{y}_i$ regression setting through estimated mean and the denominator divides the sum by n-2, not n-1, because in using to estimate, we effectively estimate two parameters — the population intercept β0 and the population slope β1. That is, we lose two degrees of freedom.

B. Peak Signal to Noise Ratio (PSNR):

PSNR is mainly generally used to measure the quality of reconstruction of lossy compression codecs. It moreover used to measure the ratio between maximum possible power of signal as well as power of corrupting noise to affects the fidelity of its representation. Usually higher PSNR represents that the creation is of higher quality, sometimes it may not. The PSNR (in dB) is defined as-

PSNR=10.log10

=20. log10

= 20. Log10(MAX1)- 10. log10 (MSE)

Where, MAXI is the maximum possible pixel value of the image

VI. RESULTS AND DISCUSSIONS

To ascertain the effectiveness of the proposed DTCWT-ABF-RE algorithm over other wavelet-domain RE techniques, different LR optical images are gathered. The image of parrots.png is chosen here for comparison with existing RE techniques. Note that the input LR image has been obtained by down sampling the original HR by a factor of 4. Figure 3 shows the original parrots.png image vs proposed DTCWT-ABF-RE image.

Figure 3: The original image vs proposed DTCWT-ABF-RE image.

It can be seen that the results of the proposed algorithm DT-CWT-ABF-RE are much better than the RE images obtained using another technique. The proposed techniques provide improved results in terms of MSE, PSNR. And the value of MSE and PSNR in dB obtained from this proposed technique is 0.0626 and 24.0667 respectively.

VII. Conclusion

An RE technique based on DT-CWT as well as an ABF filter has been proposed. Original parrots.png image selected as an input image to perform the proposed technique. Wavelet coefficients and the LR input image were interpolated using the Lanczos interpolator. And the DT-CWT is used as it is nearly shift invariant also generates less artifacts, as compared with DWT. The ABF filtering is used to overcome the artifacts generated by DT-CWT and to further enhance the performance of the planned technique in terms of MSE and PSNR value. Simulation results highlight the superior performance of proposed techniques.

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