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A Novel Image Resolution Enhancement Algorithm in Wavelet Domain

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Abstract: Increasing the number of pixel in an image without producing the appreciable degradation in the quality of the image is known as the image resolution enhancement. With the advancement in the display technology, it is possible to see the enhanced resolution of the image. Image resolution enhancement play very important role in image analysis. In medical imaging in satellite imaging, image resolution enhancement has wide application. Here this technique is used to extract detail, vital and meaningful information from the image. In the past few years with advancement in the display technology, enhanced resolution of the image is required for better viewing. This paper present a novel method of image resolution enhancement by combining the DWT and SWT. In this method interpolation in frequency domain is performed after converting the image in to frequency domain by DWT and SWT.

Keywords—Resolution, stationary wavelet transform (SWT), Discrete wavelet transform (DWT), PSNR (Peak signal to Noise Ratio)

I. INTRODUCTION

Quality and the zooming capability of the image is decided by the resolution of the image. If the resolution of the image is higher then one zoom the image to greater extent without producing the blurred. When the image is zoomed then we can see the detail information of the image closely. This is very useful for satellite as well as for medical image because in both the cases, detail information is essential for analysing the image. In satellite and medical imaging, extraction of detailed information is necessary for accurate analysis of the image. So enhancing the resolution of the image become very important in such situation. High quality digital image sensors are capable of producing the high resolution image. But these sensors have its own limitation besides it makes the digital device very costly. Specially designed high end commercial camera can produce high resolution image. Other camera can produce resolution up to 512x512. One of the cheap solution of this problem is to use some mathematical operation to produce high resolution image from low resolution captured image. Interpolation is one of the mathematical tools which is used to enhance the resolution of the image. In interpolation, some mathematical operation is performed to get the value of the missing pixel by considering the neighbouring pixel in to consideration. One of the drawback of enhancing the resolution of the image by using interpolation is that it enhance the intensity of the low frequency area of the image and also not able to preserve the high frequency area effectively.

In a broader sense, image resolution enhancement algorithm can be divided in to two part i.e. Spatial Domain Based method and Frequency domain based method. Interpolation is one of the most widely used spatial domain algorithm. In frequency domain based method, first of all the image is converted in to a frequency domain by applying some suitable transform i.e. DCT (Discrete Cosine transform), DWT (Discrete Wavelet Transform) etc... Once the image is converted in to a frequency domain then interpolation is applied in the frequency domain coefficient in increase the dimension of the missing coefficients. Once all the coefficients are interpolated then all the coefficients are converted in to a time domain to get back the high resolution image. Discrete wavelet transform is generally used in frequency domain method to convert the image in to frequency domain. Figure 1 shows the classification of the image resolution enhancement. Bi-cubic, nearest neighbourhood and bilinear are some of the common interpolation method of producing the high resolution. Among all the spatial domain method, bi-cubic based interpolation gives the best result.

In DWT, image is divided in four different frequency bands i.e. low frequency (LL). Mid frequency (LH and HL) and high frequency band (HH). Decomposition of the image in to different frequency band using DWT is shown in the figure 2. The dimension of all the four frequency band in wavelet domain decomposition is half of the dimension of the original image.

Stationary wavelet domain [2] also decompose the image in to four frequency sub-bands but

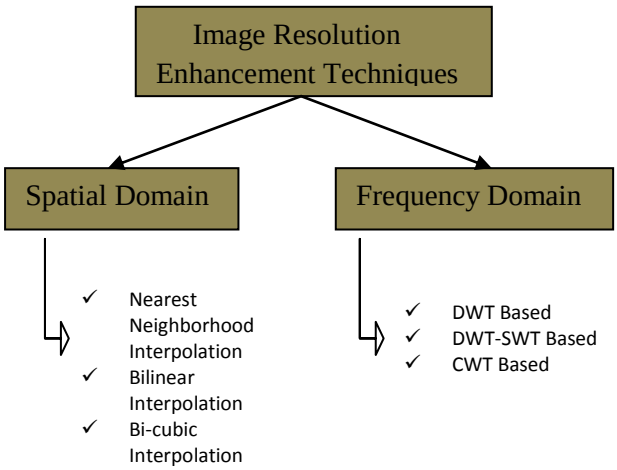


Figure 1 Classification of IR Enhancement Techniques.

in this case the dimension of all the four frequency bands are of size of the original image as shown in figure 3.

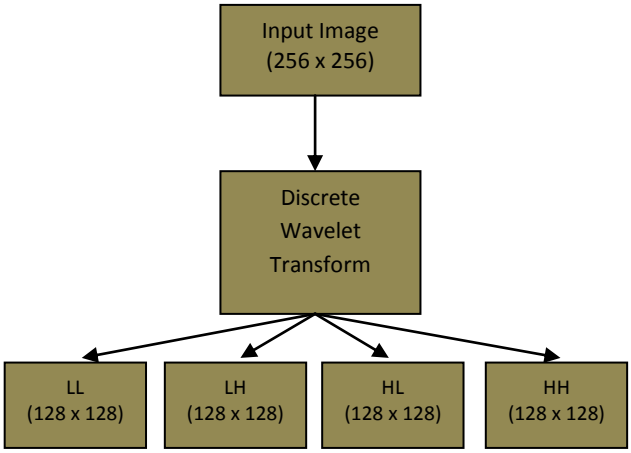


Figure 2 Frequency band Decomposition Using DWT

In the past different types of image resolution enhancement has been suggested by various authors. Resolution enhancement using interpolation in frequency domain has been suggested in the literature [3] In [3], single stage wavelet synthesis is used for getting the low frequency component while high frequency component are interpolated by a factor of 2 for getting the final high resolution image. Edge property of the image is also important to get the missing pixel value correctly. Edge property based image resolution enhancement has been presented in[4] where bilinear interpolation is combined with the adaptive interpolation method to get the high resolution image. In [5] wavelet zero padding based method is applied to get the high resolution image. In this paper author suggested a cycle spinning method for producing the high resolution image.

In [6] authors suggested a classification algorithm for the crop image which is taken through satellite using image resolution enhancement method. This paper suggested that the low resolution image gives poor image classification while the high resolution image gives better image classification.

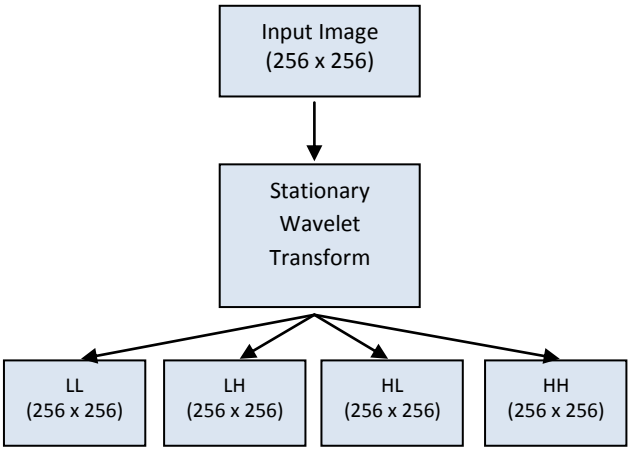


Figure 3 Frequency band Decomposition Using SWT

CT-DWT (dual tree-Complex wavelet transform) based image resolution enhancement method is proposed in [7]. In this method, dual tree complex wavelet transform is used for enhancing the resolution of the image along with the non local means.

Enhancing the resolution of the infra-red image using visible information of the image is suggested in paper [8]. In this method high resolution visible information is utilized. DWT based Image resolution enhancement [9], [10], complex wavelet transform based image resolution enhancement [11] and sparse representation based image resolution enhancement [12] are some other noteworthy contribution in this field.

II. METHODOLOGY

One of the drawbacks of the spatial domain techniques of high resolution image is that this method is not able to preserve the high frequency area of the image while converting the low resolution image in to high resolution image.

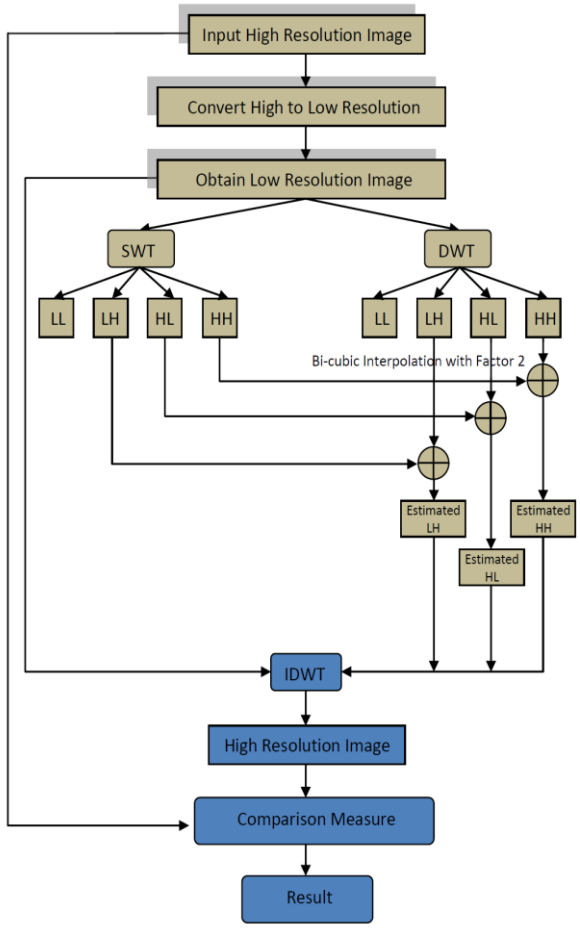


Figure 4 Block Diagram of Proposed Method

High resolution image obtained using frequency domain DWT based techniques is able to preserve the edges to some extent but this techniques even fail to retain the details of the image. In the proposed method, SWT (Stationary wavelet transforms) is incorporated to overcome this problem.

The block diagram of this techniques is shown in the figure 4 above.

In this method first of all, an high resolution image is given to the system which convert this high resolution image in to a low resolution image using average filter. This step is performed to ensure the low resolution image of the known high resolution image. This low resolution image is then fed to the system designed for the proposed method. This low resolution image is then given to the SWT Block (Stationary wavelet transform) and DWT Block (Discrete wavelet Transform). SWT as well as the DWT block both divide this low resolution image in four different frequency components i.e. LL, LH, HL and HH as shown in the figure. Here LL is the low frequency component, LH and HL are the mid frequency component and HH is the high frequency component. The major difference between DWT and SWT is that while in the former one, all the frequency component are of the dimension which is half of the dimension of the low resolution image. While the later one all the frequency components are of the same size as the size of the low resolution image. LH, HL and HH component obtained after the DWT decomposition are interpolated with the bi-cubic method to increase the dimension of theses component to double. Now since the size of these component are of same dimension of the corresponding component obtained after the SWT decomposition so these component are then added as shown in the block diagram. This step gives us the estimated value of LH, HL and HH component. In the next step IDWT (Inverse discrete wavelet transform) is performed by taking estimated LH,HL and HH and low resolution image as the LL component as shown in the figure. This inverse operation gives us the high resolution image of whose size is double the size of the low resolution image. In the next step, the quality of the produced high resolution image is compared with the original high resolution image by computing the PSNR measure.

Following are the summarized steps of algorithm of the proposed methodology-

Step 1 Take a high resolution image as input.

Step 2 Apply high to low resolution conversion operation by average filter to produce the low resolution image.

Step 3 Apply SWT based Decomposition on the low resolution image to produce the LL, LH, HL and HH frequency band of dimension of low resolution image.

Step 4 Apply the DWT based Decomposition on the low resolution image for producing the LL, LH, HL and HH frequency band of dimension which is half of the dimension of the low resolution image.

Step 5 Perform the bi-cubic interpolation method with factor 2 on LH,HL and HH to double the dimension of the LH,HL and HH band.

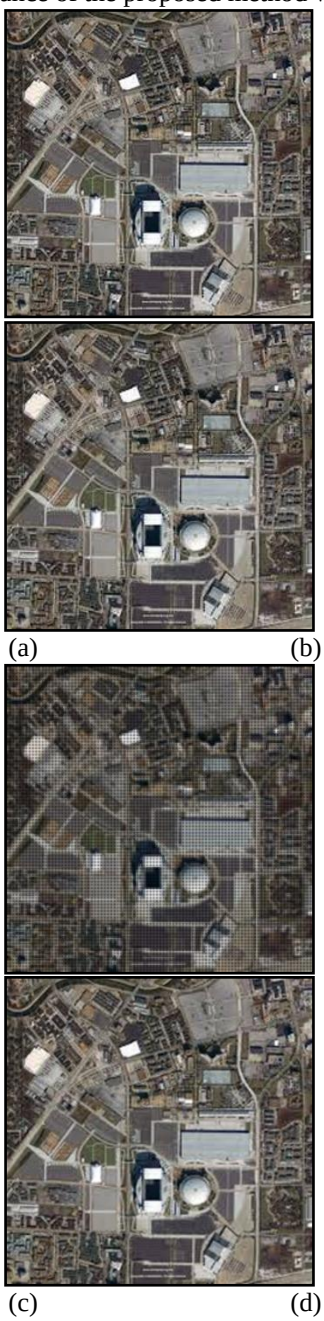
Step 6 add the LH,HL and HH band obtained in the previous step to the corresponding band obtained by SWT decomposition in step 3 to get the estimated LH, HL and HH band.

Step 7 Perform the inverse discrete wavelet transform (IDWT) by taking estimated LH,HL and HH band along with the low resolution image as the LL band to get the high resolution image.

Step 8 with the help of PSNR (Peak Signal to noise ratio), perform the quality comparison between original high resolution image and the high resolution image obtained in step 7.

III. EXPERIMENTAL RESULTS

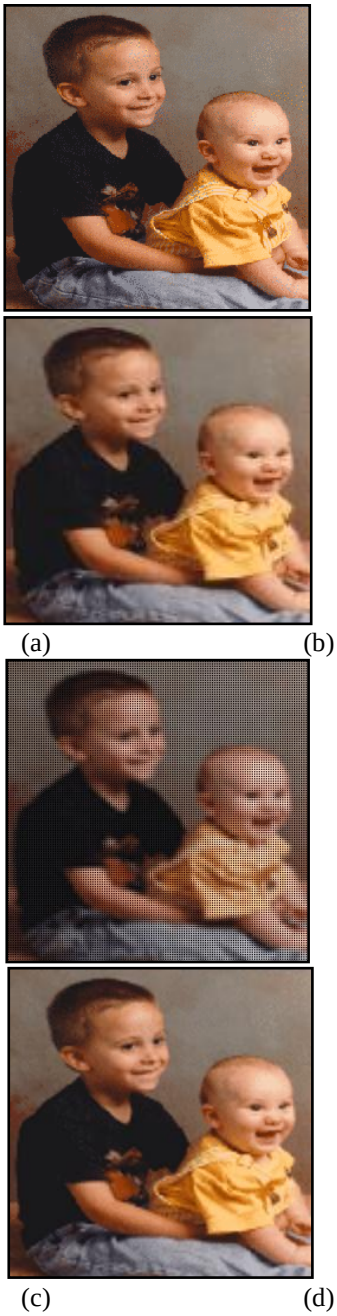
For testing the performance of the proposed method of image resolution enhancement, a set of image database has been prepared which comprises of images of different categories. Proposed method is tested for different kind of images for checking the performance. The whole system is designed in MATLAB and MATLAB version 2010 A is used for designing the simulation program. For comparing the performance of the proposed method with the previous work, one more method of image resolution enhancement is



(a) (b)

(c) (d)

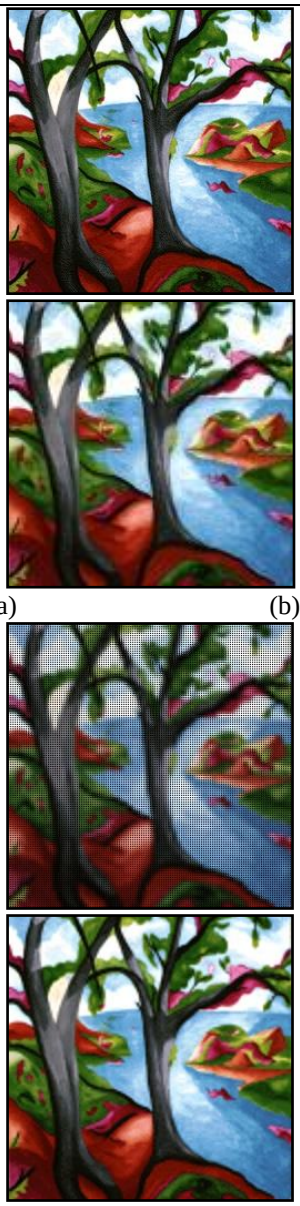
Figure 5 (a) Original High Resolution 'Sat1.jpg' Image(512x512) (b) Low resolution image(256x256) (c) HR image by DWT based Method(512x512) (d) HR image by proposed Method(512x512)



(a) (b)

(c) (d)

Figure 6 (a) Original High Resolution 'kids.jpg' Image (512x512) (b) Low resolution image (256x256) (c) HR image by DWT based Method (512x512) (d) HR image by proposed Method (512x512)



(a) (b)

(c) (d)

Figure 7 (a) Original High Resolution 'tree.jpg' Image (512x512) (b) Low resolution image (256x256) (c) HR image by DWT based Method (512x512) (d) HR image by proposed Method (512x512)

also designed which is based on the DWT decomposition only[9]. A simulation program takes the high resolution image as the input and produce the high resolution image after converting it to the low resolution image.

Images of three different categories have been taken for testing the performance. i.e. satellite image(Sat1.jpg), Simple image ('kids.jpg) and artificial image(tree.jpg). For satellite image, 'Sat1.jpg' has been taken as the input high resolution image with dimension 512x512. The size of the original high resolution image in all the three categories are 512x512. While the dimension of low resolution image is 256x256. The output of the simulation program is shown in the figure 5, figure 6 and figure 7. Figure 5(a) is original high resolution image. Figure 5 (b) is the corresponding low resolution image figure 5 (c) represent the high resolution image produced by the DWT based method while the figure 5 (d) represent the high resolution image produced by the proposed method. It is clear from this figure that the proposed method produces better visual results by preserving the edges and high frequency area. High resolution image obtained by the proposed method looks in quality in all the three categories which is clear from the figure 5,6 and 7. Moreover the high resolution image obtained by the DWT based method produce lots of grains in the image which are the false interpolation of the pixel.

Table 1 summarizes the PSNR values obtained by different method it is clear from this table that the PSNR values obtained by the proposed method is far better than the DWT based image resolution enhancement method. For computing the PSNR(Peak Signal to Noise ratio) following formula is used-

$$PSNR = 10log_{10}\frac{M \times M}{MSE}$$

Here

M= is the number of rows in the image

Table 1 PSNE Values

Image Name	PSNR (in dB)	
	DWT	Proposed
Sat1.jpg	39.9040	63.5836
Kids.jpg	38.2031	61.5391
Tree.jpg	37.0794	58.3752

And MSE is given by

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[O(i,j) - O'(i,j)]^2}{M \times N}$$

O= Original High Resolution image

O' = High resolution Image produced after applying the proposed Method

M= Total Number of rows in High Resolution Image

N= Total Number of Column in High Resolution Image

PSNR graph for the DWT based method and proposed method for different images are shown in the figure 8 for better understanding.

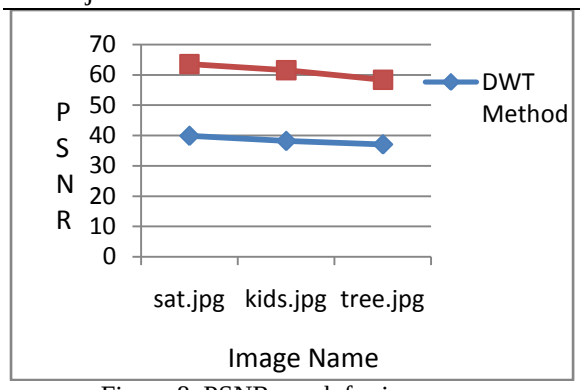


Figure 8 PSNR graph for images

IV. CONCLUSION

Image resolution enhancement is one of the vital image processing operation which is used to enhance the resolution of the image. This operation is very important in almost all the field because by enhancing the resolution, one can see the detail information of the image which makes it easy to analyse the image. In this paper we have proposed a novel method of image resolution enhancement which is combination of the discrete wavelet transform (DWT) and the Stationary wavelet Transform (SWT). Some of the drawback of the DWT based image resolution enhancement has been addressed in this paper and overcoming of theses drawback using proposed method has been presented. Simulation results confirm the superiority of this problem on the existing DWT based method.

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