Efficient Satellite Image Enhancement Technique Based On Filtering And Interpolation Methods

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Abstract

Satellite images and their applications can be found in several areas of research ranging from meteorology, forestry, seismology and oceanography. Resolution of an image has always been very important task in many image and video processing applications like feature extraction, video resolution enhancement and satellite image resolution enhancement. In this paper we have proposed a new technique of image resolution enhancement based on interpolation schemes along with DWT which is further enhanced by using filtering mechanism for noise removal. In the proposed enhancement scheme, noise is first removed by using filters followed by interpolation along with DWT which yields resolution enhanced output with contrast improvement. The proposed technique is tested on satellite benchmark images and shows its superiority over other previous techniques. PSNR and RMSE values along with visual results justify the proposed scheme and prove it to be better than other conventional and state of art techniques.

***Key words**: DWT, PSNR, RMSE, image resolution enhancement and filtering approach.*

1. Introduction

Resolution is the vital aspect for any image if it is to be used in image processing applications, because resolution enhanced image yields better results for research applications. In case of satellite images which is the topic of consideration in this paper the criteria of resolution is of utmost importance. Since satellite images needs to be analysed thoroughly for getting the finer details of the areas which are affected by like, cyclone, floods any natural disaster etc. so resolution of such types of images should be taken into consideration. Interpolation has been used long time back in image processing applications for increasing the number of pixels in an image. There are three well known interpolation techniques namely, bicubic, bilinear and nearest neighbour interpolation. Bicubic interpolation is more sophisticated than other two techniques and produced smoother edges while using nearest neighbour interpolation techniques edges were lost. Resolution enhancement using wavelets has emerged as a new technique and produces significant results. Further sharpening of image can be done by using filters. Generally we know that image is 2-dimensional so wavelet decomposition can be done by applying 1-D discrete wavelet transform along the rows and the results are then decomposed along the columns. This process yields four different sub-bands of an image namely, low-low (LL), low-high (LH), high-low (HL) and high-high (HH). Basically these sub-bands are the frequency components of the original image and cover the full spectrum of a digital image. The low-low (LL) sub-band contains the most significant information of the image while the high-high (HH) sub-band contains the least information. *Carey et al* have proposed the method to estimate the unknown details of wavelet coefficients in an order to improve the sharpness of reconstructed images. *Gholamreza Anbarjafari* and *Hasan Demirel* have proposed DWT based resolution enhancement technique. In this paper, we have proposed a resolution enhancement scheme in which filtered input image has been used whose noise has been removed followed by interpolated DWT higher frequency sub-bands. The resolution enhanced and contrast improved sharpened image has been generated by combining all these images and applying inverse DWT (IDWT) on them. The sharper image is generated by including an intermediate stage of using filters for noise removal. The final high resolution image has been generated in such a way that it is sharper and resolution enhanced as compared to original image. The proposed technique performs better when compared to all other state-of-art techniques and conventional methods. PSNR, RMSE and entropy values along with visual results show the superiority of the proposed technique and it is discussed in result analysis. All the steps of this proposed technique uses Daubechies (9/7) wavelet as the mother wavelet function and bicubic interpolation as the main interpolation function followed by filter for contrast improvement. The sub-band image generated out of an original image after applying DWT is as follows:

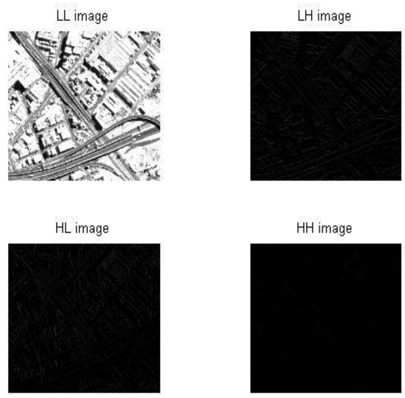


Figure 1: Sub-band images generated using DWT

The DWT filter bank structure can be shown as:

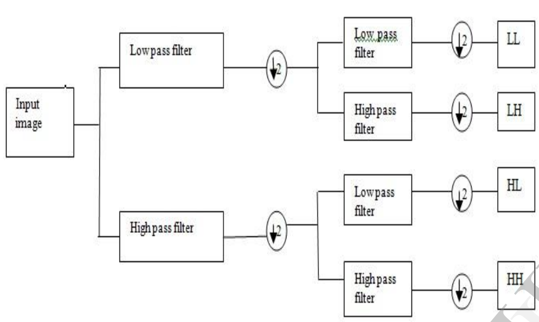


Figure 2: DWT filter bank

The paper is organised as follows: section 2 contains the overview of the state of art techniques; section 3 gives the idea about proposed resolution enhancement scheme. All the qualitative and quantitative analysis is shown in section 4 along with their comparison with previously introduced techniques and conventional state-of-art methods. Conclusion and future scope is discussed in final section.

2. State-of-art-techniques

Several methods for image enhancement have been used so far each with a different approach and improved results from previous techniques. In this paper, we have mentioned two state-of-art techniques for comparison purpose. The first one is interpolation scheme based image resolution enhancement and the second one is previously introduced DWT-based image resolution enhancement. Interpolation schemes include nearest neighbour, bilinear interpolation and bicubic interpolation methods. Results have been shown in support of the mentioned techniques to for comparison purposes.

2.1 Interpolation schemes for image resolution enhancement

Interpolation is a foremost and conventional method for image zooming or enhancement. The widely used methods for interpolation are nearest neighbour, bilinear interpolation and bicubic interpolation. Among all these *bicubic* interpolation is the most sophisticated and is used in several image processing applications. The algorithm for interpolation scheme is:

- It approximates or determines the value of grey level pixel from a set of closest pixels and assigns that value to the output pixels.
- In *nearest neighbour* interpolation grey level value is approximated from the closest pixel of input coordinates and this value is assigned to the output coordinates.
- In *bilinear* interpolation, grey level value is approximated from the weighted average of four closest pixels to input coordinates and value is assigned to the output coordinates.
- In *bicubic* interpolation, grey level value is approximated from the weighted average of sixteen closest pixels to input coordinates and value is assigned to the output coordinates.

It is clear from the given description that bicubic interpolation gives best image quality than other two techniques though it takes much processing time.

2.2 DWT-based image resolution enhancement

In this technique, DWT was used to decompose the input image into different sub-bands. DWT was applied on a low resolution input image and is decomposed into four different sub-bands as mentioned earlier. Out of these four sub-bands the low low (LL) sub-band was holding most of the high-frequency components of the image. After getting the four sub-bands bicubic interpolation was applied on each of these sub-band images to increase the number of the pixels in the image. Then the input low resolution image and low-sub-band image was used together to generate the difference image. This difference image was then applied to the interpolated sub-bands for estimation purpose. All these estimated images along with input image were then combined and inverse DWT (IDWT) was applied to give the final enhanced image. The block diagram of this technique is shown below indicating the steps followed:

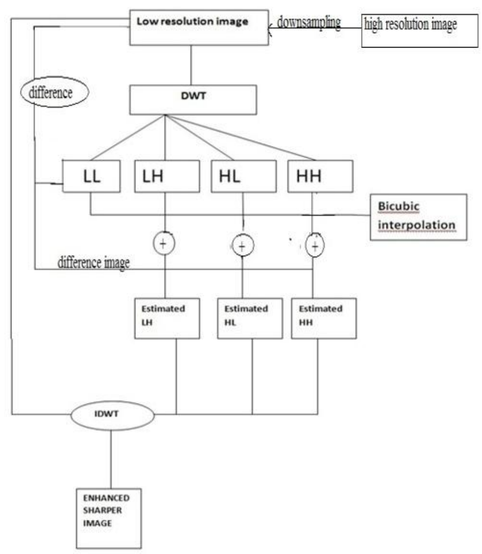


Figure 3: DWT-based enhancement technique

3. Proposed Method

As it is mentioned earlier, resolution is the vital aspect of any image and when it comes to satellite imaging this feature needs to be considered. While using the conventional interpolation methods, the main loss of an image was on its high frequency components which were due to the smoothing caused by interpolation. Edges contain the specific information of the given image. Loss of edges sometimes gives the blocky appearance of an image which is not desirable. So in order to enhance the appearance of an image, edges must be preserved. In this paper, DWT has been employed to preserve the edges of the image and filtering approach is used to make the image sharper and clearer.

DWT is applied on the input low resolution image and the image is decomposed into four different sub-bands. High frequency sub-bands contains the high frequency components of the image. The interpolation is applied on the image sub-bands. In wavelet domain, low resolution image is obtained by low-pass filtering of the high-resolution image. Using the low-low sub-band image and the original low resolution image, a difference image is created which is used in estimating the coefficients of the sub-band image. This estimation is carried out when the difference image is applied on all the higher sub-bands. The process of estimating the coefficients is further done by applying interpolation of factor 2 on all higher frequency sub-bands which is followed by another interpolation process of factor $\alpha/2$ for making the size of interpolated sub-bands suitable for IDWT process. The factor α is the enlargement factor. The difference between the low low sub-band image and the original image is between their high frequency components.

This work is further improved by using filter at the input stage. Unsharp filter is used at the input image directly and we get the filtered output. Noise has been removed from the input image and the filtered image is further down sampled to get the low resolution image. This low resolution image is then decomposed by using DWT to get the four sub-bands. These four sub-bands are then interpolated by using bicubic interpolation. Then difference image is created by using low low sub-band and the original filtered low resolution image. This difference image is used for estimation purpose. By using appropriate enlargement factor we can get the suitable size of the sub-band images to be used in IDWT process. The block diagram for proposed technique is shown below:

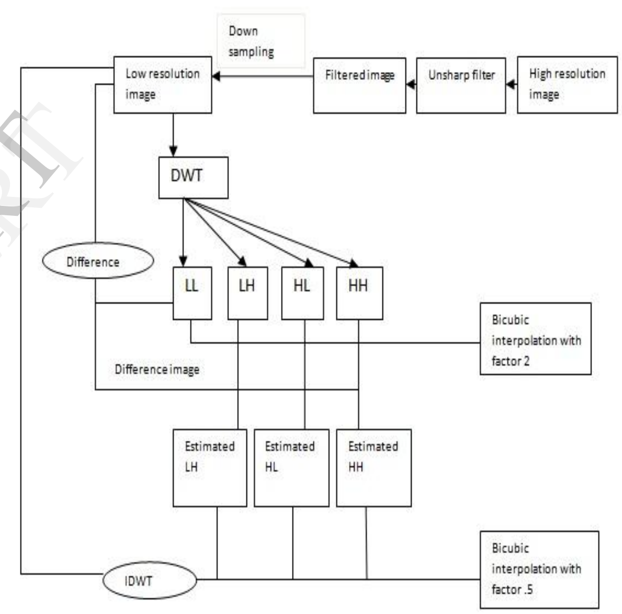


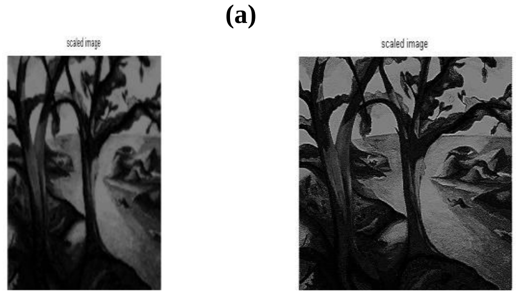
Figure 4: Proposed method for image enhancement

It can be seen clearly from the block diagram that interpolation factor of 2 is used for interpolation purpose which is again interpolated by using an enlargement factor of $\alpha/2$ or .5. An enhanced and sharper output image is obtained.

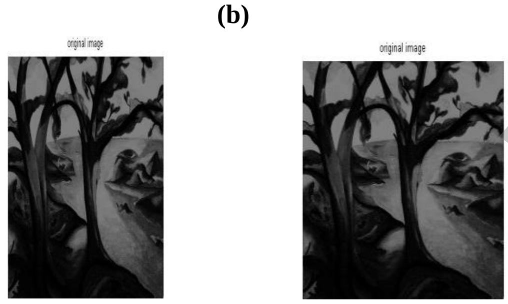
4. Result Analysis

The proposed technique has been tested on benchmark satellite images. Results have been shown which clearly indicates the superiority of the proposed method over other state-of-art techniques and conventional methods. Both visual and quantitative analysis have been done to support the proposed method.

(a)



(b)

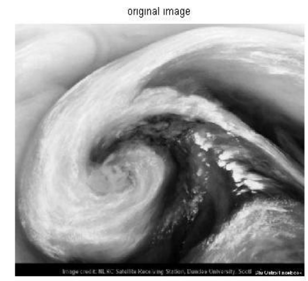


(c)

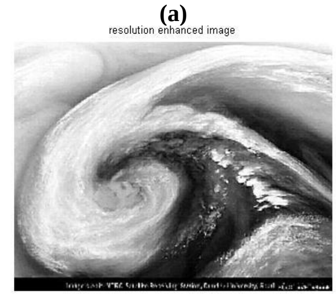
Figure 5: (a) nearest neighbour interpolation (b) bilinear interpolation (c) bicubic interpolation

In these images we can clearly see the difference among various interpolation techniques. Bicubic interpolation gives the best quality image while there is blurring in bilinear interpolated image and nearest neighbour gives the blocky appearance.

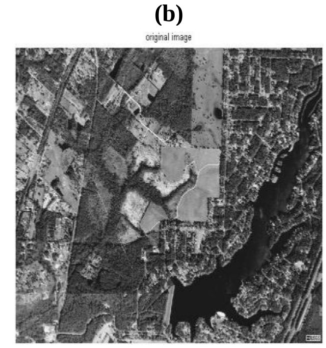
Observation showing the results of proposed method along with comparison with DWT technique alone is as follows:



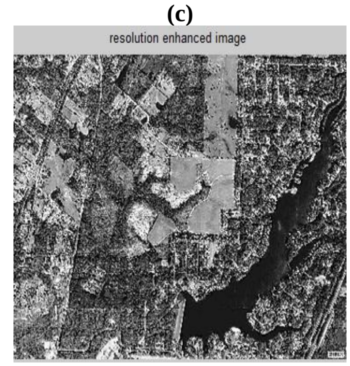
(a)



(b)

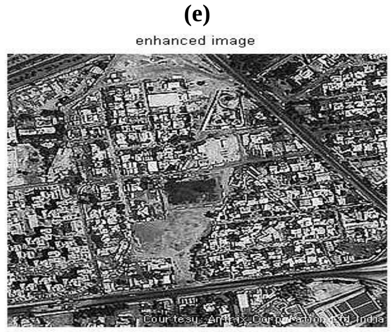


(c)



(d)

(e)



(f)

Figure 6: (a)-(b) test image 1;using dwt only and dwt with filters respectively (c)-(d) test image 2;using dwt only and dwt with filters respectively (e)-(f) test image 3;using dwt only and dwt with filters respectively

By visual point of view, we can clearly see that proposed method is superior and produces best quality output images. Not only visual results quantitative results are also shown containing the PSNR, RMSE and entropy values to prove the superiority of the proposed method.

Table 1
PSNR (db) values of the test Images

S.No.	Image Taken	Size of Image	Method	PSNR Value
1	test image 1	223x285	DWT	25.8681
	enhanced output	446x570	proposed	26.0253
2	test image 2	300x1200	DWT	23.2488
	enhanced output	600x2400	proposed	23.2947
3	test image 3	150x450	DWT	23.6589
	enhanced output	300x900	proposed	24.2625

PSNR values shown in the table clearly indicates that proposed method is superior over previously used DWT technique. Similarly we can see the RMSE and entropy values further in the tables.

PSNR (peak-signal-to-noise-ratio) values can be calculated by using the following formula:

$$PSNR = 10 \log_{10} (R^2/MSE)$$

Where R is the maximum fluctuation in the input image. MSE is the mean square error.

MSE can be calculated by the formula:

$$MSE = 1/m*n \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} [I(i,j) - K(i,j)]^2$$

Similarly RMSE is the square root of the mean square error.

Table 2
RMSE values of the test Images

S.No.	Image Taken	Method	RMSE Value
1	test image 1	DWT	11.59
	enhanced output	proposed	11.54
2	test image 2	DWT	17.54
	enhanced output	proposed	17.45
3	test image 3	DWT	16.73
	enhanced output	proposed	15.61

RMSE values also prove the superiority of the proposed technique. Now we will see the entropy values of the test images being taken.

Table 3
Entropy values of the Images

S.No.	Image Taken	Method	ENTROPY Value
1	test image 1	DWT	7.8201
	enhanced output	proposed	7.8513
2	test image 2	DWT	7.2824
	enhanced output	proposed	7.4481
3	test image 3	DWT	6.6647
	enhanced output	proposed	7.7254

We have analysed the quantitative results as shown in the table 1, 2 and 3 respectively

5. Conclusion

This paper has presented a new image enhancement technique based on the combination of DWT and filtering approach. So the noise has been removed from the input image by directly applying filters on it. The visual results have clearly shown the superiority of the proposed method over previously introduced DWT technique. We got the sharper and enhanced output image in the results being shown. Not only visual but quantitative results also support the proposed method over other conventional and state-of-art techniques.

6. References

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