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Robust Satellite Image Resolution Enhancement Based On Interpolation Of Stationary Wavelet Transform

M.S.Divya Lakshmi

Abstract— In this paper an image resolution enhancement technique based on interpolation of the high frequency subband images obtained by discrete wavelet transform (DWT) and the difference image. The edges are enhanced by introducing an intermediate stage by using stationary wavelet transform (SWT). DWT is applied in order to decompose an input image into different Subbands. Then the high Frequency subbands as well as the difference image are interpolated. The estimated high frequency subbands are being modified by using high frequency subband obtained through SWT. Then all these subbands are combined to generate a new high resolution, low contrast satellite image by using inverse DWT (IDWT). The GHE is the contrast enhancement technique applied to high resolution, low contrast satellite image thus we finally obtain high resolution, high contrast satellite image. The quantitative and visual results are showing the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques.

Index Terms— Discrete wavelets transform (DWT), stationary wavelet transform (SWT), generalized histogram equalization (GHE), interpolation, intermediate stage, high resolution, contrast enhancement technique.

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1 Introduction

SATELLITE imagery includes photographs of the earth taken through an artificial satellite revolving around the earth. The process of correcting these satellite images for haze, cloud and sensor induced defects within satellite image and overlaying the 2D satellite image on 3D surface of the earth is called satellite image processing. Processed satellite images have different scientific and need based applications in the field of agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence and warfare.

Satellite imagery is usually the most cost efficient means of collecting regular and frequent data about the earth's surface. These data are routinely used to monitor land use change, urban expansion, agricultural health and productivity, the status of urban tree corridors, fire threat, species distributions, environmental condition and many, many other phenomena.

Satellite imagery is also used in seismology and oceanography in deducing changes to land formation, water depth and sea bed, by color caused by earthquakes, volcanoes, and tsunamis. For every digital satellite image the pixel value represents the magnitude of an observed characteristic such as brightness level. The smallest unit that constitutes the picture is a picture element called pixel. Each point in the image or scene is represented by an integer digital number (DN) usually 256 (0 to 255), normally in the dynamic range of the display device the lowest intensity of the parameter where no signal is assigned to DN value zero and the highest intensity or largest signal to 255, the intermediate intensities receiving appropriate intermediate DN value.

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2 Enhancement Technique

Image enhancement is the process of improving the quality of the digital image without knowledge about the source of degradation.resolution and contrast are the two important attributes of an image.

Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. Image enhancement plays key role in digital processing so we focus on the importance of the representation of information for various image processing tasks. The way in which manipulation of information is represented brings out certain types of features while hiding others. Signal compression and estimation applications also rely heavily on having an efficient representation of image data; we would like to approximate a signal with a few numbers of parameters. Therefore, we seek a transform which yields an efficient representation while bringing out the de sired features of the signal one of the commonly used techniques for image Resolution enhancement is Interpolation.

2.1 Interpolation

Interpolation has been widely used in many Image processing applications such as facial reconstruction, multiple description coding, and super resolution. There are three well known interpolation techniques, namely nearest neighbour interpolation, bilinear interpolation, and bicubic interpolation. Image resolution enhancement in the wavelet domain is a relatively new research topic and recently many new algorithms have been proposed.

2.2 Overviw of SWT and DWT

Discrete wavelet transform (DWT) is one of the recent wavelet transforms used in image processing. DWT decomposes an image into different subband images, namely low-

low (LL), low high (LH), high-low (HL), and high-high (HH). Another recent wavelet transform which has been used in several image processing applications is stationary wavelet transform (SWT). In short, SWT is similar to DWT but it does not use down-sampling, hence the subbands will have the same size as the input image. In this work, we are proposing an image resolution enhancement technique which generates sharper high resolution image. The Proposed technique uses DWT to decompose a low resolution image into different subbands. Then the three high frequency subband images have been interpolated using bicubic interpolation. The high frequency subbands obtained by SWT of the input image are being incremented into the interpolated high frequency subbands in order to correct the estimated coefficients. In parallel, the input low resolution, low contrast image and interpolated LL subband of SWT are subtracted to obtain difference image to obtain sharper edges in the final high resolution image. Finally, corrected interpolated high frequency subbands and difference image are combined by using inverse DWT (IDWT) to achieve a high resolution output image. Then GHE is applied to obtain high contrast satellite image. The proposed technique has been compared with conventional and state of-art image resolution enhancement techniques.

According to the quantitative and qualitative experimental results, the proposed technique over performs the Conventional and state-of-art techniques for image resolution enhancement.

3 PROPOSED SWT BASED IMAGE RESOLUTION ENHANCEMENT

Image resolution enhancement is the process of manipulating an image so that resultant image is more suitable than the original one for specific application. Image enhancement can be done in various domains. For image resolution enhancement there are many methods, out of which image interpolation scheme is one of the most effective method. However, resolution is vital aspect of any image. Good quality image i.e. high resolution image produces better result in image processing applications. Thus we first deal with satellite image resolution enhancement then with satellite image contrast enhancement.

An interpolation is the technique to increase the resolution of the image by selecting new pixel from surrounding one. Image interpolation in wavelet transform is produces better results for any imaging application. DWT technique is used to improve the resolution of any satellite image. Image interpolation is widely used resolution enhancement method for various applications. Image interpolation is the process of using known data to estimate values at unknown locations. Interpolation method select new pixel from surrounding pixels.

In image resolution enhancement by using interpolation the main loss is on its high frequency components (i.e., edges), which is due to the smoothing caused by interpolation. In order to increase the quality of the super resolved image, preserving the edges is essential. In this work, DWT has been employed in order to preserve the high frequency components of the image. The redundancy and shift invariance of the DWT

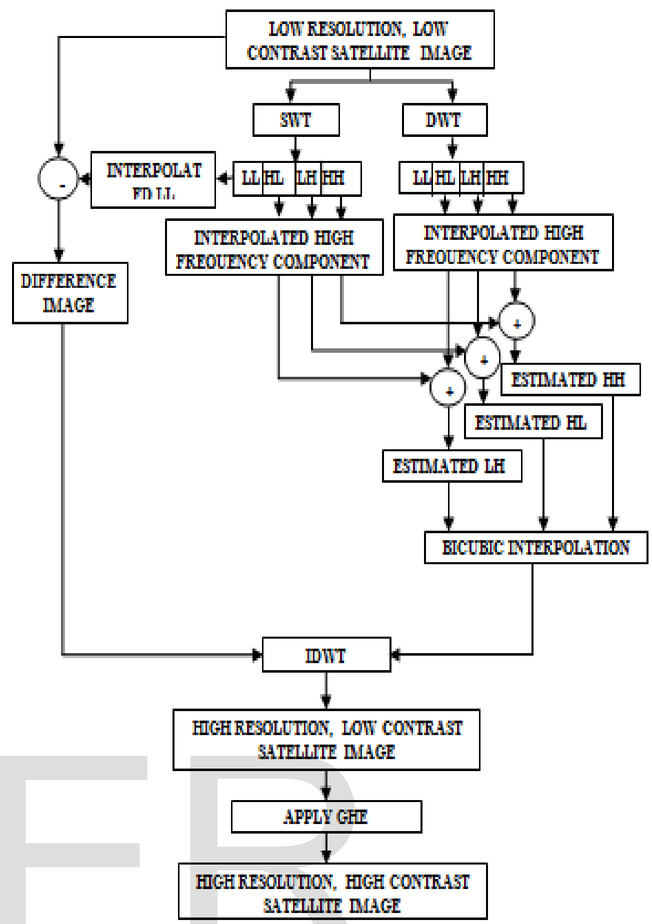

Fig. 1. Block diagram of SWT based satellite image resolution and contrast enhancement.

mean that DWT coefficients are inherently interpolable. In this correspondence, one level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different subband images. Three high frequency subbands (LH, HL, and HH) contain the high frequency components of the input image.

In the Proposed technique, bicubic interpolation with enlargement factor of 2 is applied to high frequency subband images. Down sampling in each of the DWT subbands causes information loss in the respective subbands. That is why SWT is employed to minimize this loss. The interpolated high frequency subbands and the SWT high frequency subbands have the same size which means they can be added with each other. The new corrected high frequency subbands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution image is obtained by low pass filtering of the high resolution image. In other words, low frequency subband is the low resolution of the original image.Therefore, instead of using low frequency subband, which contains less information than the original low resolution im-

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age; we are using the difference image by difference of input image and interpolation of low frequency subband of SWT image. Using difference image obtained in intermediate stage instead of low frequency subband increases the quality of the super resolved image. Fig. 1 illustrates the block diagram of the proposed image resolution enhancement technique. By interpolating high frequency subbands by 2 and α in the intermediate and final interpolation stages respectively, and then by applying IDWT, as illustrated in Fig. 1, the output image will contain sharper edges than the interpolated image obtained by interpolation of the input image directly. This is due to the fact that, the interpolation of isolated high frequency components in high frequency subbands and using the corrections obtained by adding high frequency subbands of SWT of the input image, will preserve more high frequency components after the interpolation than interpolating input image directly.

The interpolated high frequency component after applying SWT and interpolated high frequency components after applying DWR are added to make new estimated high frequency component then we apply bicubic interpolation. IDWT was applied to Interpolated estimate high frequency component and the difference image. Thus we obtain high resolution, low contrast satellite image. GHE was applied to enhance contrast of satellite image.GHE is simple effective method for contrast enhancement which consists of generating an output image with a uniform histogram. In image processing the idea of equalizing a histogram is to stretch the original histogram using entire range of discrete levels of the image.GHE is a commonly used for image contrast enhancement since it is computationally fast and simple to implement. Thus we obtain high resolution, high contrast satellite image.

4 Result and Discussion

Fig. 2 shows that super resolved image of Eiffel tower satellite image using proposed technique in (g) are much better than the low resolution, low contrast input image in (a), after applying DWT for input image with four subbands shown in fig.2 (b). After applying SWT for input image with four subbands shown in fig.2 (c). Fig.2 (d) is the bicubic interpolated estimated high frequency component of satellite image. Fig.2 (e) high resolution, low contrast image after applying IDWT and the histogram of the image is shown in fig.2 (f). fig.2 (g) is the high resolution, high contrast satellite image and the histogram of the image is shown in fig.2(h).The image enhancement performance is evaluated using mean square error, root mean square error, peak signal to noise ratio (PSNR) and entropy shown in table 1.

In table 1the MSE, RMSE value was low in final high resolution, hig contrast satellite image compared to the input low resolution, low contrast satellite image and high resolution, low contrast satellite image. Thus the PSNR value was better in final output image.

Fig. 2 (a).input low resolution, low contrast Eiffel tower satellite image .

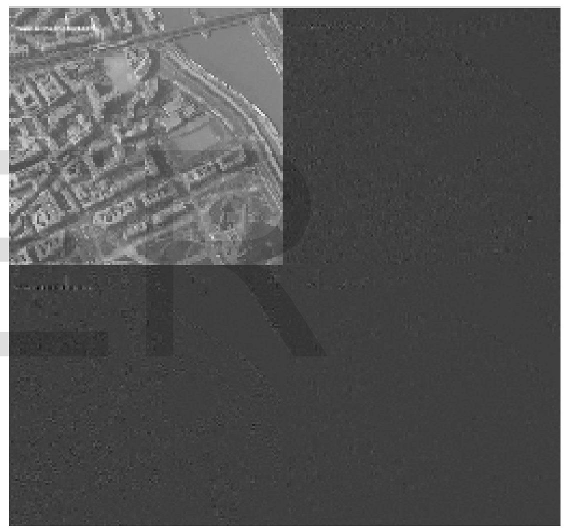

Fig. 2(b). DWT applied input image.

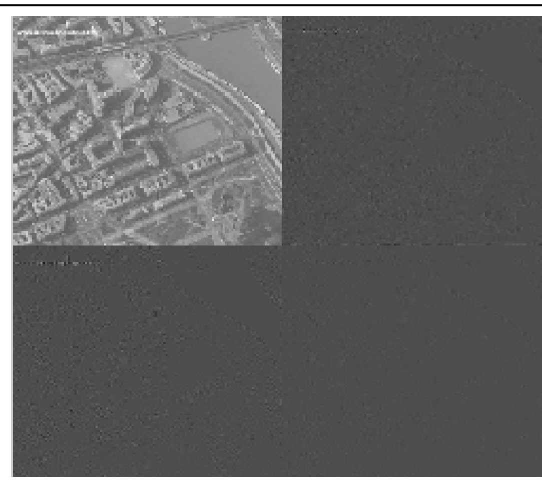

Fig. 2(c). SWT applid input image.

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Fig. 2(d). Bicubic interpolated estimated high frequency satellite image.

Fig. 2(e). High resolution, low contrast satellite image.

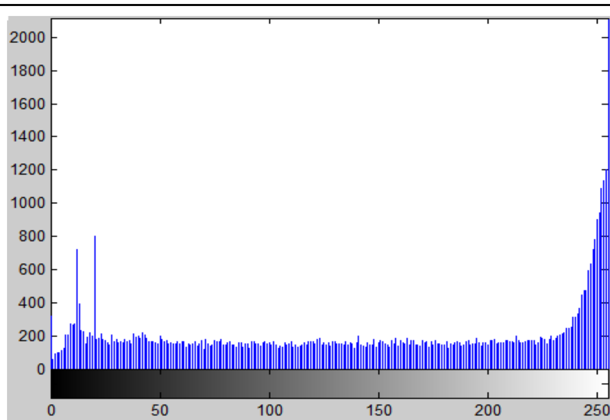

Fig. 2(f). Histogram of High resolution, low contrast satellite image fig.2(e).

Fig. 2(g). High resolution, high contrast satellite image.

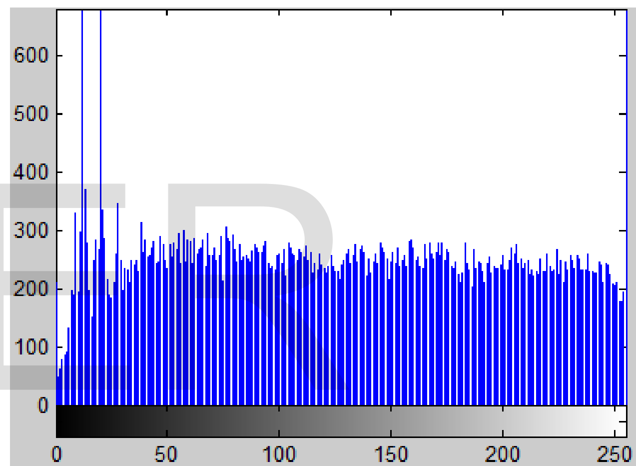

Fig. 2(h). Histogram of. high resolution, high contrast satellite image fig.2(g).

TABLE 1
COMPARISON OF MSE, RMSE, PSNR(DB), ENTROPY VALUES OF SATELLITE IMAGE

Eiffel tower satellite image	Low resolution, low contrast input image	High resolution, low contrast image	High resolution, high contrast output image
MSE	968.46	135.72	82.43
RMSE	31.12	11.65	9.08
PSNR(db)	17.42	26.84	28.97
ENTROPY	2.975	4.876	5.937

MSE=mean square error,RMSE=root mean square error,PSNR=peak signal to noise ratio(db).

MSE is error metrics used to compare image enhancement quality. The MSE represents the cumulative squared error between the enhanced and the original image. MSE is representing the mean square error between the given input image I_{in} and the original image I_{org} which can be obtained by the following:

$$MSE = \frac{\sum_{i,j} (I_{in}(i,j) - I_{org}(i,j))^2}{M \times N} \quad (1)$$

$$PSNR = 10 \log 10 \left(\frac{R^2}{MSE} \right) \quad (2)$$

Where M and N are the size of the images. The error is the amount by which the value implied by the estimator differs from the quality to be estimated. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate.

Peak signal to noise ratio (PSNR) measures the degree of enhancement in satellite image PSNR is given in equation (2). Where, R is the maximum possible pixel value of the input image data type. MSE is mean square error. MSE measures the average of the squares of the errors. The maximum value of PSNR indicates higher degree of noise reduction. Thus the high resolution, high contrast image have high PSNR value compared to input and low contrast image. We obtain better MSE, RMSE, PSNR, and ENTROPY value which shows that proposed enhancement technique is better than enhancement technique.

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4 Conclusion

The proposed technique has been tested on well-known benchmark images, where their PSNR and visual results show the superiority of proposed technique over the conventional image resolution enhancement techniques. The image resolution enhancement technique based on the interpolation of the high frequency sub-bands obtained by DWT, correcting the high frequency sub-band estimation by using SWT high frequency sub-bands, and the difference image. The proposed technique uses DWT to decompose an image into different sub-bands, and then the high frequency sub-band images have been interpolated. The interpolated high frequency sub-band coefficients have been corrected by using the high frequency sub-bands achieved by SWT of the input image. An estimated high frequency subband is interpolated with half of the interpolation factor used for interpolation the high frequency sub-bands of SWT and DWT. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. Here we are using interpolation to gets the robustness. The proposed technique has been tested on well-known benchmark images, where their PSNR, RMSE, MSE, ENTROPY and visual results show the superiority of proposed technique over the conventional and state-of-art image resolution enhancement techniques.

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References

[1] Hasan Demirel and Gholamreza Anbarjafari "Discrete Wavelet Transform-Based Satellite Image Resolution Enhancement" IEEE Trans. Geoscience and remote sensing,vol.49, no.6, pp. 1997-2004, June 2011.

[2] Hasan Demirel and Gholamreza Anbarjafari," Image Resolution Enhancement by Using Discrete and Stationary Wavelet Decomposition" IEEE Transactions on Image Processing, Vol. 20, NO. 5, MAY 2011.

[3] T. Celik, C. Direkoglu, H. Ozkaramanli, H. Demirel, and M. Uyguroglu, "Region-based super-resolution aided facial feature extraction from low resolution video sequences," in Proc. IEEE ICASSP, Philadelphia, PA, vol. II, pp. 789–792, Mar. 2005.

[4] H. Demirel and G. Anbarjafari, "Satellite image resolution enhancement using complex wavelet transform," IEEE Geosci. Remote Sens. Lett., vol. 7, no. 1, pp. 123–126, Jan. 2010.

[5] L. Yi-bo, X. Hong, and Z. Sen-yue, "The wrinkle generation method for facial reconstruction based on extraction of partition wrinkle line features and fractal interpolation," in Proc. 4th ICIG, Aug. 22–24, 2007, pp. 933–937.

[6] Y.Rener, J. Wei, and C. Ken, "Down sample-based multiple description coding and post-processing of decoding," in Proc. 27th CCC, pp. 253–256, Jul. 16–18, 2008.

[7] Y. Piao, L. Shin, and H. W. Park, "Image resolution enhancement using intersubband correlation in wavelet domain," in Proc. IEEE ICIP, vol. 1, pp. I-445–I-448, 2007.

[8] G.Anbarjafari and H. Demirel, "Image super resolution based on interpolation of wavelet domain high frequency subbands and the spatial domain input image," ETRI J., vol. 32, no. 3, pp. 390–394, Jun. 2010.

[9] W. K. Carey, D. B. Chuang, and S. S. Hemami, "Regularity-preserving image interpolation," IEEE Trans. Image Process., vol. 8, no. 9, pp. 1295– 1297, Sep. 1999.

[10] X. Li and M. T. Orchard, "New edge-directed interpolation," IEEE Trans. Image Process., vol. 10, no. 10, pp. 1521–1527, Oct. 2001.

[11] K. Kinebuchi, D. D. Muresan, and T.W. Parks, "Image interpolation using wavelet based hidden Markov trees," in Proc. IEEE ICASSP, vol. 3, pp. 7–11, 2001.

[12] M. S. Crouse, R. D. Nowak, and R. G. Baraniuk, "Wavelet-based statistical signal processing using hidden Markov models," IEEE Trans. Signal Process., vol. 46, no. 4, pp. 886–902, Apr.1998.

[13] S. Zhao, H. Han, and S. Peng, "Wavelet domain HMT-based image super resolution," in Proc. IEEE ICIP, vol. 2, pp. 933–936 ,Sep. 2003.

[14] A. Temizel and T. Vlachos, "Image resolution up scaling in the wavelet domain using directional cycle spinning," J. Electron. Imaging, vol. 14, no. 4, pp.504-510, 2005

[15] V. A. Tolpekin and A. Stein, "Quantification of the effects of land-cover class spectral separability on the accuracy of Markov-random-field-based super resolution mapping," IEEE Trans. Geosci. Remote Sens., vol. 47, no. 9, pp. 3283–3297, Sep. 2009.

[16] A. Temizel and T. Vlachos, "Wavelet domain image resolution enhancement using cycle-spinning," IEEE Electronic. Let t., vol. 41, no. 3, pp. 119–121,Feb. 3, 2005.