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IMAGE ENHANCEMENT BASED ON DISCRETE WAVELET TRANSFORM

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ABSTRACT

In this paper, a new satellite image resolution enhancement technique based on the interpolation of the high frequency sub bands obtained by discrete wavelet transform (DWT) and the input image is proposed. The projected resolution improvement technique uses DWT to decay the input image into different sub bands. Then, the high frequency sub band images and the input low resolution image have been interpolated, followed by combining all these images to generate a new resolution enhanced image by using inverse DWT. In order to achieve a sharper image, an intermediate stage for estimating the high frequency sub bands has been proposed. The proposed technique has been tested on satellite benchmark images. The quantitative (peak signal to noise ratio and root mean square error) and visual results show the superiority of the proposed technique over the conventional and state of art image resolution enhancement techniques.

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KEY WORDS
Discrete wavelet transform; resolution; peak signal to noise ratio; mean square error

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INTRODUCTION

Satellite images are used in many applications such as geosciences studies, astronomy, and geographical information systems. One of the most important quality factors in images comes from its resolution. Interpolation in image processing is a well known method to increase the resolution of a digital image. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple descriptions coding, and resolution enhancement. A new framework for statistical signal processing based on wavelet-domain hidden Markov models (HMM's) that concisely models the statistical dependencies and non-Gaussian statistics encountered in real-world signals is developed in [1]. Efficient expectation maximization algorithms are developed for fitting the HMM's to observational signal data.

A wavelet domain image resolution enhancement algorithm is developed in [2]. A primary high-resolution approximation to the original image is obtained by means of WZP and is further processed using the CS methodology which reduces ringing. An efficient edge algorithm is used for the description of edge degradations such as blurring due to loss of resolution. Linear regression using a minimal training set of high-resolution originals is finally employed to rectify the degraded edges. A multiple description image coding scheme is proposed to facilitate the transmission of images over media with possible packet loss and is based on finding the optimal reconstruction filter coefficients that will be used to reconstruct lost descriptions in [3].

For this purpose initially, the original image is down sampled and each sub image is coded using standard JPEG. These decoded images are then mapped to the original image size using the optimal filters. Interpolation of the high-frequency sub band images obtained by dual-tree complex wavelet transform (DT-CWT) is proposed in [4]. DT-CWT is used to decompose an input low-resolution satellite image into different sub bands. Then, the high-frequency sub band images and the input image are interpolated, to generate a new HR image by using inverse DT-CWT. The resolution enhancement is achieved by using directional selectivity provided by the CWT, where the high-frequency sub bands in six different directions contribute to the sharpness of the high-frequency details such as edges. Super resolution is used for resolution enhancement of images or video sequences. Instead of super resolving frames globally, using localized motion based super resolution increases the quality of the enhanced frames. The super resolution on different sub bands of localized moving regions extracted from discrete wavelet transform (DWT) and composing the super resolved sub bands using inverse DWT (IDWT) to generate the respective enhanced high resolution frame in [5].

MATERIALS AND METHODS

The proposed Image Enhancement system is based on DWT. In this following section the theoretical background of all the approaches are introduced.

Discrete Wavelet Transform

Nowadays, wavelets have been used quite frequently in image processing and used for feature extraction, de-noising, compression, face recognition, and image super-resolution. The decomposition of images into different frequency ranges permits the isolation of the frequency components introduced by "intrinsic deformations" or "extrinsic factors" into certain sub-bands. This process results in isolating small changes in an image mainly in high frequency sub-band images.

The 2-D wavelet decomposition of an image is performed by applying 1-D DWT along the rows of the image first, and, then, the results are decomposed along the columns. This operation results in four decomposed sub-band images referred to as low–low (LL), low–high (LH), high–low (HL), and high–high (HH). The frequency components of those sub-band images as shown in Figure 1 (b) cover the frequency components of the original image in Fig. 1 (a).

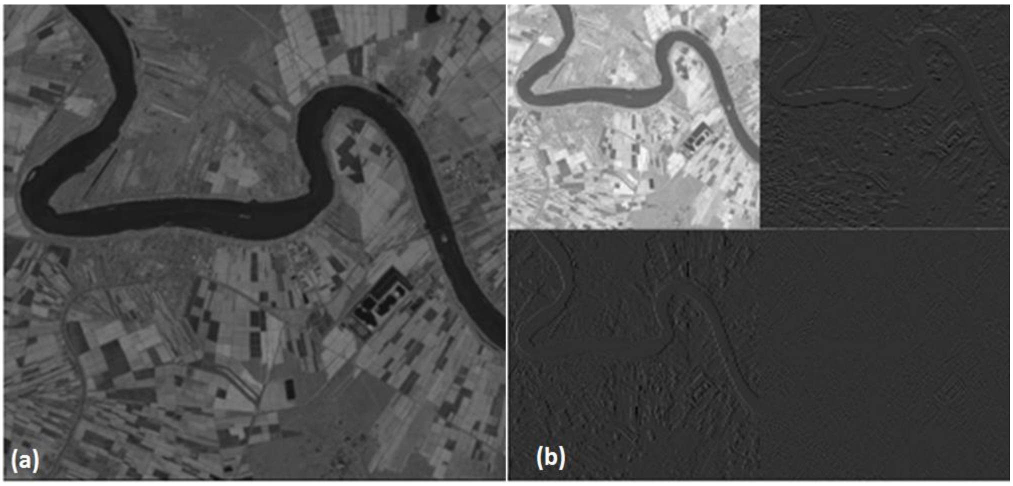

Fig. 1(a): Input Image **(b)** 2-D Wavelet decomposition

Interpolation Techniques

Interpolation is the process of estimating the values of a continuous function from discrete samples. Image processing applications of interpolation include image magnification or reduction, sub pixel image registration, to correct spatial distortions, and image decompression, as well as others. Of the many image interpolation techniques available, nearest neighbor, bilinear and cubic convolution are the most common, and will be talked about here. Since, Interpolation provides a perfect reconstruction of a continuous function, provided that the data was obtained by uniform sampling at or above the Nyquist rate. Since Interpolation does not give good results within an image processing environment, since image data is generally acquired at a much lower sampling rate. The mapping between the unknown high-resolution image and the low-resolution image is not invertible, and thus a unique solution to the inverse problem cannot be computed. One of the essential aspects of interpolation is efficiency since the amount of data associated with digital images is large.

Bilinear Interpolation

Bilinear Interpolation determines the grey level value from the weighted average of the four closest pixels to the specified input coordinates, and assigns that value to the output coordinates. First, two linear interpolations are performed in one direction and then one more linear interpolation is performed in the perpendicular direction. For one-dimension Linear Interpolation, the number of grid points needed to evaluate the interpolation function is two. For Bilinear Interpolation (linear interpolation in two dimensions), the number of grid points needed to evaluate the interpolation function is four [6].
For linear interpolation, the interpolation kernel is:

$$u(s) = \{0 \mid s \mid > 1$$
$$\{1 - \mid s \mid \mid s \mid < 1$$

where, is the distance between the point to be interpolated and the grid point being considered. The interpolation coefficients

Bicubic Convolution Interpolation

Cubic Convolution Interpolation determines the grey level value from the weighted average of the 16 closest pixels to the specified input coordinates, and assigns that value to the output coordinates. The image is slightly sharper than that produced by Bilinear Interpolation, and it does not have the disjointed appearance produced by Nearest Neighbour Interpolation. First, four one-dimension cubic convolutions are performed in one direction and then one more one-dimension cubic convolution is performed in the perpendicular direction. This means that to implement a two-dimension cubic convolution, a one-dimension cubic convolution is all that is needed. For one-dimension Cubic Convolution Interpolation, the

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number of grid points needed to evaluate the interpolation function is four, two grid points on either side of the point under consideration. For Bicubic Interpolation (cubic convolution interpolation in two dimensions), the number of grid points needed to evaluate the interpolation function is16, two grid points on either side of the point under consideration for both horizontal and vertical directions [7] .

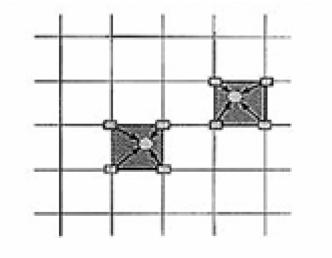

Fig. 2: Bilinear Interpolation

RESULTS

DWT has been employed in order to preserve the high-frequency components of the image. DWT separates the image into different sub and images, namely, LL, LH, HL, and HH. High-frequency sub-bands contain the high frequency component of the image. The interpolation can be applied to these four sub band images. In the wavelet domain, the low-resolution image is obtained by low-pass filtering of the high-resolution image as in, and. The low resolution image (LL sub band), without quantization (i.e., with double-precision pixel values) is used as the input for the proposed resolution enhancement process.

In other words, low frequency sub band images are the low resolution of the original image. Therefore, instead of using low-frequency sub band images, which contains less information than the original input image, we are using this input image through the interpolation process. Hence, the input low-resolution image is interpolated with the half of the interpolation factor, α/2, used to interpolate the high-frequency sub bands. In order to preserve more edge information, i.e., obtaining a sharper enhanced image, we have proposed an intermediate stage in high frequency sub band interpolation process. As shown in Fig. 5, the low-resolution input satellite image and the interpolated LL image with factor 2 are highly correlated. The difference between the LL sub band image and the low-resolution input image are in their high-frequency components.

Hence, this difference image can be use in the intermediate process to correct the estimated high-frequency components. This estimation is performed by interpolating the high-frequency sub bands by factor 2 and then including the difference image (which is high-frequency components on low-resolution input image) into the estimated high-frequency images, followed by another interpolation with factor α/2 in order to reach the required size for IDWT process.

The intermediate process of adding the difference image, containing high-frequency components, generates significantly sharper and clearer final image. This sharpness is boosted by the fact that, the interpolation of isolated high-frequency components in HH, HL, and LH will preserve more high-frequency components than interpolating the low-resolution image directly. Certain improvement in the paper is also made actually the paper speaks about the gray scale image but here we use the same principle to the RGB image.

DISCUSSION

The quantitative (peak signal to noise ratio and root mean square error) and visual results show the superiority of the proposed technique over the conventional and state of art image resolution enhancement techniques.

Table 1: Relationship between MSE and PSNR values

Name of the image	MSE	PSNR(db)
Sample.jpg	0.47514	51.3626
Sample1.jpg	0.2817	53.633
Sample2.jpg	0.3544	52.525
Sample3.jpg	0.45554	50.875

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From the Table 1, it is clear that lower the MSE value, higher the PSNR value.

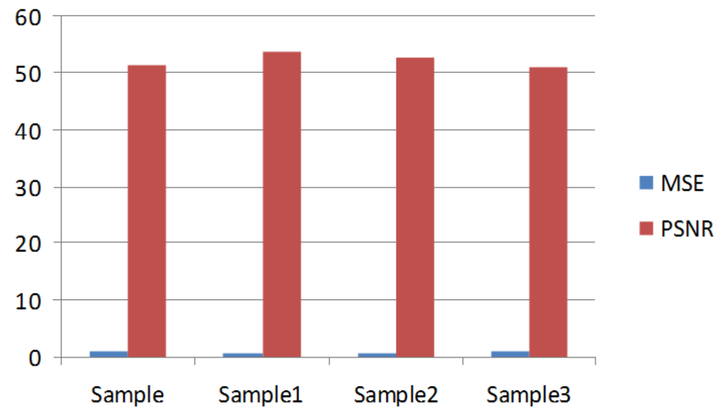

Fig. 3: Graphical Representation of MSE and PSNR

CONCLUSION

This paper has proposed a new resolution enhancement technique based on the interpolation of the high-frequency sub band images obtained by DWT and the input image. The proposed technique has been tested on well-known benchmark images, where their PSNR and MSE and visual results show the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques

CONFLICT OF INTEREST
There is no conflict of interest.

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FINANCIAL DISCLOSURE
None.

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