Image Resolution Enhancement by Using Multi Resolution Transform-DWT

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ABSTRACT

In this paper we propose an image resolution enhancement technique based on the interpolation of high-frequency subbands obtained by discrete wavelet transform (DWT) and the input image. The proposed resolution enhancement technique uses DWT to decompose the input image into different subbands. Then, the high-frequency subband 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 state to estimate the high frequency sub bands by utilizing the difference image obtained by subtracting the input image and its interpolated LL sub band. The proposed technique has been tested on well-known benchmark images. The quantitative (peak signal to noise ratio) and visual results show the superiority of the proposed technique over the conventional and state-of art image resolution enhancement techniques.

***Keywords* -** Discrete wavelet transform(DWT), image resolution enhancement, Interpolation, peak signal to noise ratio(PSNR).

I. INTRODUCTION

Image interpolation[5] occurs in all digital photos at some stage — whether this be in bayer demosaicing or in photo enlargement. It happens anytime you resize or remap (distort) your image from one pixel grid to another. Image resizing is necessary when you need to increase or decrease the total number of pixels, whereas remapping can occur under a wider variety of scenarios: correcting for lens distortion, changing perspective, and rotating an image. Even if the same image resize or remap is performed, the results can vary significantly depending on the interpolation algorithm. It is only an approximation, therefore an image will always lose some quality each time interpolation is performed.

Common interpolation algorithms can be grouped into two categories: adaptive and non-adaptive. Adaptive methods change depending on what they are interpolating (sharp edges vs. smooth texture), whereas non-adaptive methods treat all pixels equally. Non-adaptive algorithms include: nearest neighbor, bilinear, bicubic, spline, sinc, lanczos and others. Depending on their complexity, these use anywhere from 0 to 255 (or more) adjacent pixels when interpolating. The more adjacent pixels they include, the more accurate they can become, but this comes at the expense of much longer processing time. These algorithms can be used to both distort and resize a photo. Adaptive algorithms include many proprietary algorithms in licensed software such as: Qimage, Photo Zoom Pro, Genuine Fractals and others. Many of these apply a different version of their algorithm (on a pixel-by-pixel basis) when they detect the presence of an edge — aiming to minimize unsightly interpolation artifacts in regions where they are most apparent. Basic interpolation techniques are described below.

A. Nearest Neighbor Interpolation

Nearest neighbor[8] is the most basic and requires the least processing time of all the interpolation algorithms because it only considers one pixel — the closest one to the interpolated point. This has the effect of simply making each pixel bigger.

B. Bilinear Interpolation

Bilinear interpolation[7][8] considers the closest 2x2 neighborhood of known pixel values surrounding the unknown pixel. It then takes a weighted average of these 4 pixels to arrive at its final interpolated value. This results in much smoother looking images than nearest neighbor.

C. Bicubic Interpolation

Bicubic[7] goes one step beyond bilinear by considering the closest 4x4 neighborhood of known pixels — for a total of 16 pixels. Since these are at various distances from the unknown pixel, closer pixels are given a higher weighting in the calculation. Bicubic produces noticeably sharper images than the previous two methods, and is perhaps the ideal combination of processing time and output quality.

Wavelets[4] are also playing a significant role in many image processing applications. Fig.1[7] shows the 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform (DWT)[1] along the rows of the image first, and then finally, corrected interpolated high frequency sub bands and interpolated input image are combined with the help of inverse DWT (IDWT) to achieve a high resolution output image. The results are decomposed into columns. This operation results in four decomposed sub band images called low low(LL), low-high (LH), high-low (HL), and high-high (HH).The frequency components of these sub bands cover the full frequency spectrum of the original image. Image resolution enhancement[1] using wavelets is a relatively a new subject and recently many new algorithms have been proposed. Their task was carried out by investigating the evolution of wavelet transform extreme among the same type of sub bands. Edges identified by an edge detection algorithm[6] in lower frequency sub bands were used to prepare a model used for estimating edges in higher frequency sub bands and only the coefficients with significant values were estimated as the evolution of the wavelet coefficients.

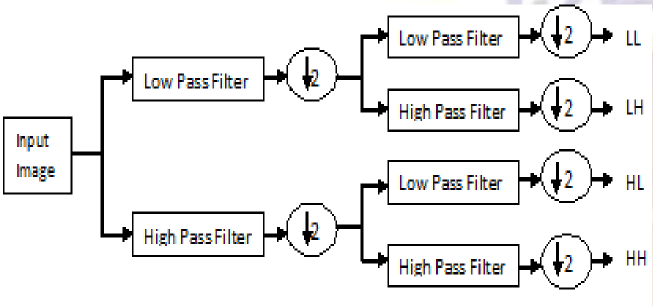

Fig. 1. Block diagram of DWT filter banks of level 1.

In this paper we propose an image resolution enhancement technique which generates sharper high resolution images. The proposed resolution enhancement technique uses DWT to decompose the input image into different subbands. Then, the high-frequency subband 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 state to estimate the high frequency sub bands by utilizing the difference image obtained by subtracting the input image and its interpolated LL sub band. In all steps of the proposed image resolution enhancement technique, Daubechies wavelet transform as mother wavelet function and bi-cubic interpolation as interpolation technique have been used. The proposed technique has been compared with standard interpolation techniques, wavelet zero padding (WZP)[3], where the unknown coefficients in high-frequency subbands are replaced with zeros, and state-of-art techniques, such as Demirel-Anbarjafari Super Resolution (DASR) technique, and DWT-SWT based Super Resolution Image enhancement technique.

II. Existing Techniques

The main loss in image resolution enhancement by using interpolation is on its high frequency components (i.e., edges), which is due to the smoothing caused by interpolation. Edges plays very important role in image. To increase the quality of the super resolved image, it is essential to preserve all the edges in image. In work[1], DWT has been employed in order to preserve the high frequency components of the image(i.e. edges). Some state-of-art techniques are:

A. DASR Technique

Demiel-Anbarjafari Super Resolution (DASR) technique[2] uses discrete wavelet transform (DWT) to decompose a low resolution image into different subband images. Then the high frequency subband images are interpolated using bicubic interpolation. In parallel, the input image is also interpolated separately. Finally, the interpolated high-frequency subband images and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high-resolution output image.

B. DWT-SWT Based SR Technique

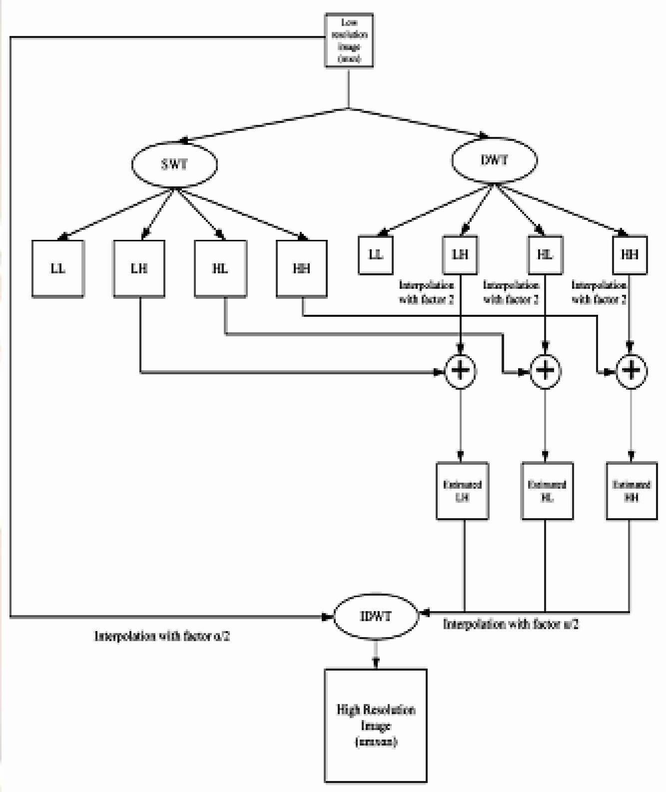

Fig. 2. Block diagram of the DWT-SWT SR technique

This technique uses Discrete Wave Transform(DWT) to decompose a low resolution image into three high frequency sub-bands. Then these sub-band images have been interpolated with the help of bi-cubic interpolation. The high frequency sub-bands obtained by SWT of the input image are converted into the interpolated high frequency sub-bands. This helps in correcting the estimated coefficients. In addition the input image is also interpolated separately. Finally, corrected interpolated high frequency sub-bands and interpolated input image are combined by using a method called inverse DWT (IDWT) to achieve a high resolution output images shown in Fig.2[1]. In all steps of the proposed image resolution enhancement technique, Daubechies wavelet transform as mother wavelet function and bi-cubic interpolation as interpolation technique have been used. 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(i.e. edges). In this technique, bicubic interpolation with enlargement factor of 2 is applied to high frequency subband images. Information loss occur due to down sampling in each of the DWT subbands caused in the respective subbands. That is why SWT (Stationary Wavelet Transform)[1] is used to minimize this loss.

III. Proposed Technique

Resolution[2] is an important feature in satellite imaging, which makes the resolution enhancement of such images is a vital importance as increasing the resolution of these images will directly affect the performance of the system using these images as input. The main loss of an image after being resolution enhanced by applying interpolation is on its high-frequency components, which is due to the smoothing caused by interpolation method. Thus, in order to increase the quality of the enhanced image, preserving the edges is essential. In this paper, DWT has been used in order to preserve the high-frequency components of the image. DWT separates the image into several sub band images, namely, LL, LH, HL, and HH. A high-frequency subband contains the high frequency components 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 images. 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 subband images are the low resolution of the original image, we are using this input image through the interpolation process.

The input low-resolution image is interpolated with the half of the interpolation factor, $\alpha/2$, used to interpolate the high-frequency sub bands, as shown in Fig. 3. In order to get 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.3, the low-resolution input 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 obtained 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 $\alpha/2$ 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 than interpolating the low-resolution image directly.

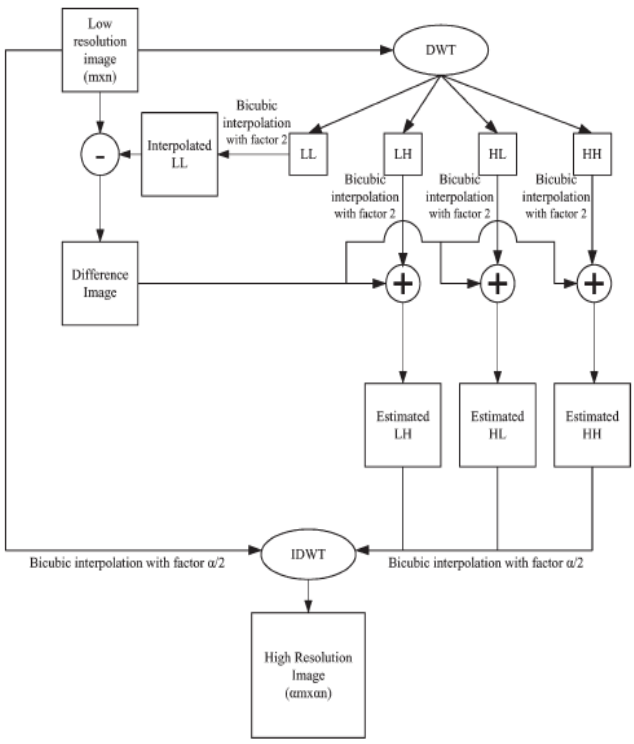

Fig. 3. Block diagram of the proposed resolution enhancement algorith

IV. Results And Discussions

The proposed technique has been tested on several different images. In order to show the superiority of the proposed method over the conventional and state-of-art techniques from visual point of view Fig. 4 (a)-(d) are included. In those figures with low-resolution image, the enhanced images by using bilinear, enhanced image by using DWT-SWT SR technique and also the enhanced images obtained by the proposed technique are shown. It clear that the resultant image, enhanced by using the proposed technique, is sharper than the other techniques.

Peak signal-to-noise ratio (PSNR) and root mean square error (RMSE) have been implemented in order to obtain some quantitative results for comparison. PSNR[3] can be obtained by using the following formula :

$$PSNR = 10.\log_{10}\left(\frac{R^2}{MSE}\right) \qquad (1)$$

high-quality product, Where R is the maximum fluctuation in the image and MSE is representing the MSE between the given input image I_{in} and the output image I_{out} which can be obtained by the following Eq. (2) :

$$MSE = \frac{1}{M \times N}\sum_{i-0}^{M-1}\sum_{j=0}^{N-1}[I_{in}(i,j) - I_{out}(i,j)]^2 \qquad (2)$$

Where M and N are the size of the images.
Higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction.

TABLE I. PSNR RESULTS FOR RESOLUTION ENHANCEMENT FROM 128X128 TO 512X512.

Techniques/Images	**PSNR(dB)**		
	Baboon	***Lena***	***Satellite***
Bilinear Interpolation	27.71	26.34	22.42
Bicubic Interpolation	29.68	26.84	23.13
Wavelet zero padding	34.86	28.84	24.21
DASR Technique	34.98	34.79	28.27
DWT-SWT SR	35.04	36.87	28.56
Proposed Technique	35.51	35.04	29.08

Table.1 is showing the comparison among the proposed method , some conventional techniques, and also some state-of-art resolution enhancement technique by means of calculating PSNR by using Eq. (1).

V. CONCLUSION

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

The PSNR improvement of the proposed technique will be increased as compared with the standard bi-cubic interpolation. An original image is interpolated with the half of the interpolation factor used for interpolation the high frequency sub bands. Afterwards all these images have been combined using IDWT method to generate a super resolved image.

Fig. 4. (a) Original low resolution Lena image. (b) Bilinear interpolation. (c) DWT-SWT SR technique. (d) Proposed technique.

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