

Discrete and Stationary Wavelet Decomposition for IMAGE Resolution Enhancement

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Abstract— An image resolution enhancement technique based on interpolation of the high frequency subband images obtained by discrete wavelet transform (DWT) and the input 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 input 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 image by using inverse DWT (IDWT). The quantitative and visual results are showing the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques.

Keywords— Discrete wavelet transform, image super resolution, stationary wavelet transform.

I. INTRODUCTION

Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been widely used in many image processing applications such as facial reconstruction [1], multiple description coding [2], and super resolution [3]-[6]. There are three well known interpolation techniques, namely nearest neighbor 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 [4]-[7]. Discrete wavelet transform (DWT) [8] is one of the recent wavelet transforms used in image processing. DWT decomposes an image into different subband images, namely low-low (LL), lowhigh (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) [9]. 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 image is also interpolated separately.

Finally, corrected interpolated high frequency subbands and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high resolution output image. The proposed technique has been compared with conventional and state-of-art image resolution enhancement techniques. The conventional techniques used are the following:

- interpolation techniques: bilinear interpolation and bicubic interpolation;
- wavelet zero padding (WZP).

The state-of-art techniques used for comparison purposes are the following:

- regularity-preserving image interpolation [7];
- new edge-directed interpolation (NEDI) [10];
- hidden Markov model (HMM) [11];
- HMM-based image super resolution (HMM SR) [12];
- WZP and cycle-spinning (WZP-CS) [13];
- WZP, CS, and edge rectification (WZP-CS-ER) [14];
- DWT based super resolution (DWT SR) [15];
- complex wavelet transform based super resolution (CWT SR) [5]

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

II. BACKGROUND

Mathematical transformations are applied to signals to obtain further information from that signal that is not readily available in the raw signal. In the following tutorial I will assume a time-domain signal as a raw signal, and a signal that has been "transformed" by any of the available mathematical transformations as a processed signal. There are number of transformations that can be applied, among which the Fourier transforms are probably by far the most popular. Most of the signals in practice are TIME-DOMAIN signals in their raw format. That is, whatever that signal is measuring, is a function of time.

In other words, when we plot the signal one of the axes is time (independent variable), and the other (dependent variable) is usually the amplitude. When we plot time-domain signals, we obtain a time-amplitude representation of the signal. This representation is not always the best representation of the signal for most signal processing related applications. In many cases, the most distinguished information is hidden in the frequency content of the signal. The frequency SPECTRUM of a signal is basically the frequency components (spectral components) of that signal.

The frequency spectrum of a signal shows what frequencies exist in the signal. Intuitively, we all know that the frequency is something to do with the change in rate of something. If something (a mathematical or physical variable, would be the technically correct term) changes rapidly, we say that it is of high frequency, where as if this variable does not change rapidly, i.e., it changes smoothly, we say that it is of low frequency. If this variable does not change at all, then we say it has zero frequency, or no frequency.

III. PROPOSED IMAGE RESOLUTION ENHANCEMENT

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 mean that DWT coefficients are inherently interpolable [9].

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. Downsampling 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 lowpass filtering of the high resolution image [16]. 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 high resolution image, we are using the input image for the interpolation of low frequency subband image. Using input image 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 input image by $\alpha/2$, and 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.

Interpolation:

One of the commonly used techniques for image resolution enhancement is 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 neighbor interpolation, bilinear interpolation, and bicubic interpolation. Interpolation is the process of using known data values to estimate unknown data values. Various interpolation techniques are often used in the atmospheric sciences.

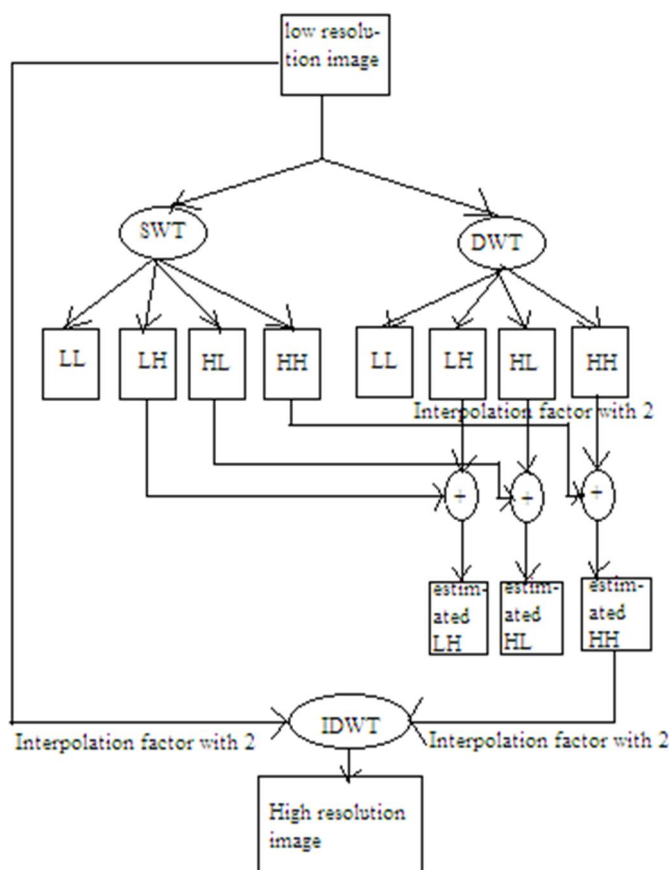


Fig. 1 Block diagram of the proposed super resolution algorithm.

A. Nearest Neighbour Interpolation

Nearest-neighbor interpolation (also known as proximal interpolation or, in some contexts, point sampling) is a simple method of multivariate interpolation in one or more dimensions. Interpolation is the problem of approximating the value for a non-given point in some space when given some colors of points around (neighboring) that point. The nearest neighbor algorithm selects the value of the nearest point and does not consider the values of neighboring points at all, yielding a piecewise-constant interpolant. The algorithm is very simple to implement and is commonly used (usually along with bimappping) in real-time 3D rendering to select color values for a textured surface.

Bilinear interpolation:

In computer vision and image processing, bilinear interpolation is one of the basic resampling techniques.

In texture mapping, it is also known as bilinear filtering or *bilinear texture mapping*, and it can be used to produce a reasonably realistic image. An algorithm is used to map a screen pixel location to a corresponding point on the texture map. A weighted average of the attributes (color, alpha, etc.)

of the four surrounding pixels is computed and applied to the screen pixel. This process is repeated for each pixel forming the object being textured.

When an image needs to be scaled up, each pixel of the original image needs to be moved in a certain direction based on the scale constant. However, when scaling up an image by a non-integral scale factor, there are pixels (i.e., *holes*) that are not assigned appropriate pixel values. In this case, those *holes* should be assigned appropriate RGB or grayscale values so that the output image does not have non-valued pixels.

Bilinear interpolation can be used where perfect image transformation with pixel matching is impossible, so that one can calculate and assign appropriate intensity values to pixels. Unlike other interpolation techniques such as nearest neighbor interpolation and bicubic interpolation, bilinear interpolation uses only the 4 nearest pixel values which are located in diagonal directions from a given pixel in order to find the appropriate color intensity values of that pixel. Bilinear interpolation considers the closest 2x2 neighborhood of known pixel values surrounding the unknown pixel's computed location. It then takes a weighted average of these 4 pixels to arrive at its final, interpolated value. The weight on each of the 4 pixel values is based on the computed pixel's distance (in 2D space) from each of the known points.

B. Bicubic Interpolation

In mathematics, bicubic interpolation is an extension of cubic interpolation for interpolating data points on a two dimensional regular grid. The interpolated surface is smoother than corresponding surfaces obtained by bilinear interpolation or nearest-neighbor interpolation. Bicubic interpolation can be accomplished using either Lagrange polynomials, cubic splines, or cubic convolution algorithm. In image processing, bicubic interpolation is often chosen over bilinear interpolation or nearest neighbor in image resampling, when speed is not an issue. Images resampled with bicubic interpolation are smoother and have fewer interpolation artifacts.

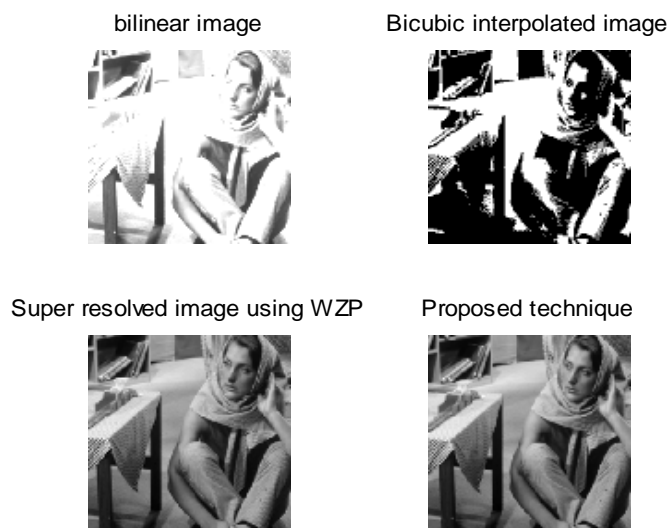
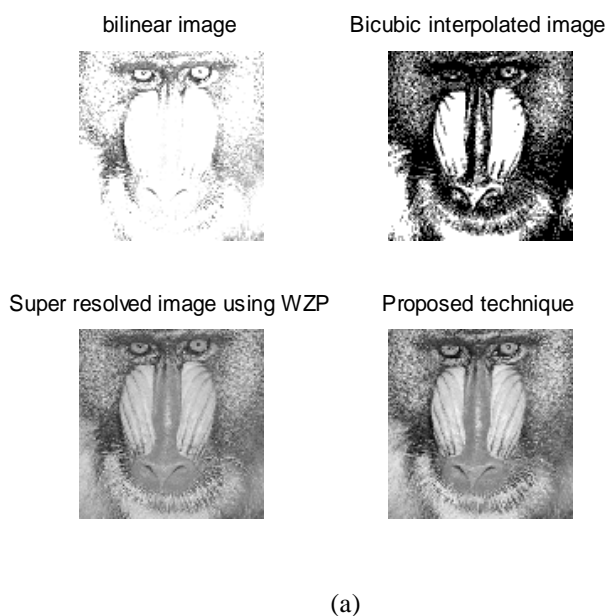
we are proposing an image resolution enhancement technique which generates sharper high resolution image. The proposed technique uses DWT to decompose a low resolution image into different subbands. Then the three high frequency subband images have been interpolated using bicubic interpolation.

TABLE I
PSNR (DB) RESULTS FOR RESOLUTION ENHANCEMENT FROM 128 X 128 TO 512 X 512 OF THE PROPOSED TECHNIQUE COMPARED WITH THE CONVENTIONAL AND STATE-OF-ART IMAGE RESOLUTION ENHANCEMENT TECHNIQUES.

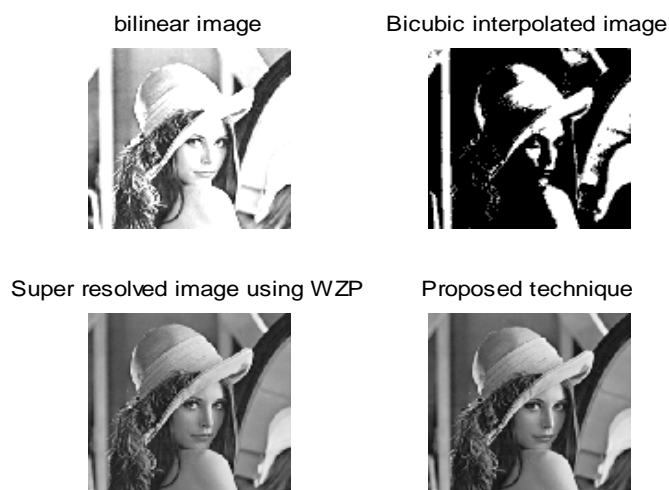
Techniques\images	PSNR(dB)		
	Baboon	Barbara	Lean
Bilinear	27.71	28.07	29.28
Bicubic	29.69	30.11	31.30
WZP	34.81	35.25	36.28
Proposed Technique	34.98	35.62	36.74

IV. SIMULATION RESULTS

Fig. 2 shows that super resolved image of (a) Baboon, (b) Barbara, and (c) Lena's picture using proposed technique are much better than the low resolution image in super resolved image by using the interpolation, and WZP. Note that the input low resolution images have been obtained by down-sampling the original high resolution images. In order to show the effectiveness of the proposed method over the conventional and state-of-art image resolution enhancement techniques, four well-known test images (Lena, Baboon, and barbara) with different features are used for comparison.



(b)



(c)

Fig. 2 (a)Baboon, (b) Barbara,(c)Lena

Table I compares the PSNR performance of the proposed technique using bicubic interpolation with conventional and state-of-art resolution enhancement techniques: bilinear, bicubic, WZP, NEDI, HMM, HMM SR, WZP-CS, WZP-CS-ER, DWT SR, CWT SR, and regularity-preserving image interpolation. Additionally, in order to have more comprehensive comparison, the performance of the super resolved image by using SWT only (SWT-SR) is also included in the table. The results in Table I indicate that the proposed technique over-performs the aforementioned conventional and state-of-art image resolution enhancement techniques. Table I also indicates that the proposed technique

over-performs the aforementioned conventional and state-of-art image resolution enhancement techniques.

V. CONCLUSIONS

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency subbands obtained by DWT, correcting the high frequency subband estimation by using SWT high frequency subbands, and the input image. The proposed technique uses DWT to decompose an image into different subbands, and then the high frequency subband images have been interpolated. The interpolated high frequency subband coefficients have been corrected by using the high frequency subbands achieved by SWT of the input image. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency subbands. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. 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 and state-of-art image resolution enhancement techniques.

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