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Discrete and Stationary Wavelet Analysis for Augmentation of Image Resolution

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Abstract — **Traditional methods used to increase the image resolution is image interpolation but the potential problem associated with it is to magnify the image many times without loss in image clarity. In this letter, we propose a technique for augmentation of image resolution based on wavelets which has a certain capability to analyze non-stationary signals. The discrete wavelet transform and unprocessed image is used to obtain interpolation of the high frequency sub-band images. In intermediate stage stationary wavelet transform is used to enhance the edges of image. The decomposition of input image to obtain frequency sub-bands is done by discrete wavelet transform. Then the high frequency sub-bands as well as the input image are interpolated. The high frequency sub-bands obtained by SWT are being used to modify estimated high frequency sub-bands. Then inverse discrete wavelet transform is used to combine all these sub-bands from which a new high resolution image is generated. The quantitative peak signal-to-noise ratio (PSNR) and enhanced visual features of the subject images shows the superiority of the proposed technique over the conventional bilinear, bicubic interpolation and wavelet zero padding based image resolution enhancement techniques.**

Index Terms— **Image interpolation, Discrete and stationary wavelet transform, PSNR.**

I. INTRODUCTION

Processing on image is such an area which is completely characterized by the need for extensive experimental work to establish the viability of proposed solutions to a given problem. An important characteristic underlying the design of image processing systems is the significant level of testing & experimentation that normally required before arriving at an acceptable solution. This characteristic implies that the ability to formulate approaches & quickly prototype candidate solutions generally plays a major role in reducing the cost & time required to arrive at a viable system implementation.

There are no clear-cut boundaries in the continuum from image processing at one end to complete vision at the other. However, one useful paradigm is to consider three types of computerized processes in this continuum: low-, mid-, & high-level processes. Low-level process involves primitive operations such as image processing to reduce noise, contrast enhancement & image sharpening. A low- level process is characterized by the fact that both its inputs & outputs are images. Mid-level process on images involves tasks such as segmentation, description of that object to reduce them to a form suitable for computer processing & classification of individual objects. A mid-level process is characterized by the fact that its inputs generally are images but its outputs are attributes extracted from those images. Finally higher- level processing involves “Making sense” of an ensemble of recognized objects, as in image analysis & at the far end of the continuum performing the cognitive functions normally associated with human vision.

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 pro- posed [4]–[7]. Discrete wavelet transform (DWT) [8] is one of the re cent wavelet transforms used in image processing. Decomposition of 2-D Image by using DWT is shown in figure 1. DWT decomposes an image into different sub-band 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) [9]. In short, SWT is similar to DWT but it does not use down-sampling, hence the sub-bands will have the same size as the input image.

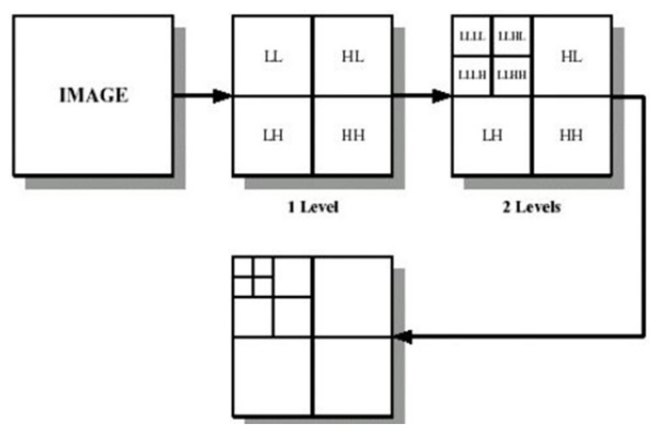

Fig. 1. Wavelet decomposition of 2-D image.

In this work, we are proposing an image resolution enhancement technique which generates sharper high resolution image. The pro- posed technique uses DWT to decompose a low resolution image into different sub-bands. Then the three high frequency sub-band images have been interpolated using bicubic interpolation. The high frequency sub- bands obtained by SWT of the input image are being incremented into the interpolated high frequency sub-bands in order to correct the estimated coefficients. In parallel, the input image is also interpolated separately. Finally, corrected interpolated high frequency sub-bands 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:

a. Interpolation techniques:
   Bilinear interpolation
   Bicubic interpolation;
b. Wavelet zero padding (WZP).

Figure 2.b) shows the expected augmented resolution image obtained from given database image having low resolution.

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.

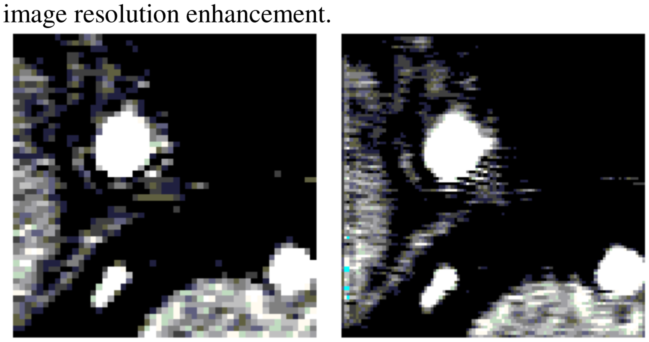

Fig. 2. (a) Original image resolution
(b) Augmented resolution image.

II. PROPOSED METHODOLOGY

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 sub-band images. Three high frequency sub-bands (LH, HL, and HH) contain the high frequency components of the input image. In the pro posed technique, bicubic interpolation with enlargement factor of 2 is applied to high frequency sub-band images. Down sampling in each of the DWT sub-bands causes information loss in the respective sub-bands. That is why SWT is employed to minimize this loss.

The interpolated high frequency sub-bands and the SWT high frequency sub-bands have the same size which means they can be added with each other. The new corrected high frequency sub-bands 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 [16]. In other words, low frequency sub-band is the low resolution of the original image. Therefore, instead of using low frequency sub-band, which contains less information than the original high resolution image, we are using the input image for the interpolation of low frequency sub-band image. Using input image instead of low frequency sub-band increases the quality of the super resolved image. Fig. 3 illustrates the block diagram of the proposed image resolution enhancement technique.

By interpolating input image by 2 , and high frequency sub-bands by 2 and in the intermediate and final interpolation stages respectively, and then by applying IDWT, as illustrated in Fig. 3, 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 sub-bands and using the corrections obtained by adding high frequency sub-bands of SWT of the input image, will preserve more high frequency components after the interpolation than interpolating input image directly.

III. RESULTS AND DISCUSSIONS

Fig. 5 shows that super resolved image of Man's picture using proposed technique in (d) are much better than the low resolution image in (a), super resolved image by using the interpolation (b), and WZP (c).

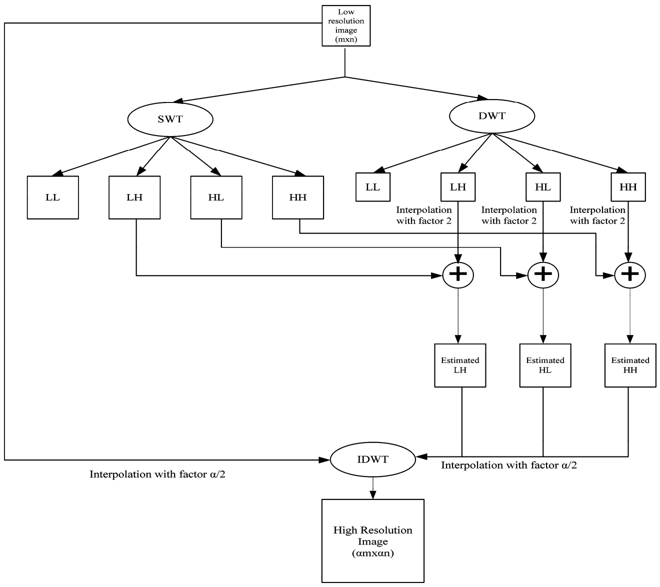

Fig. 3. Block diagram of the proposed super resolution algorithm.

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 test images (Taj, Man, Girl and Bhakti) with different features are used for comparison.

Visual inspection of picture of Taj shown in Figure 4 clearly indicates the superiority of proposed method.

Fig. 4. (a) Bilinear interpolated image (b)Bicubic interpolated image.
(c) Proposed technique.

Table I compares the PSNR performance of the proposed technique using bilinear method, bicubic method, Wavelet Zero padding technique and proposed method by using DWT and SWT. 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.

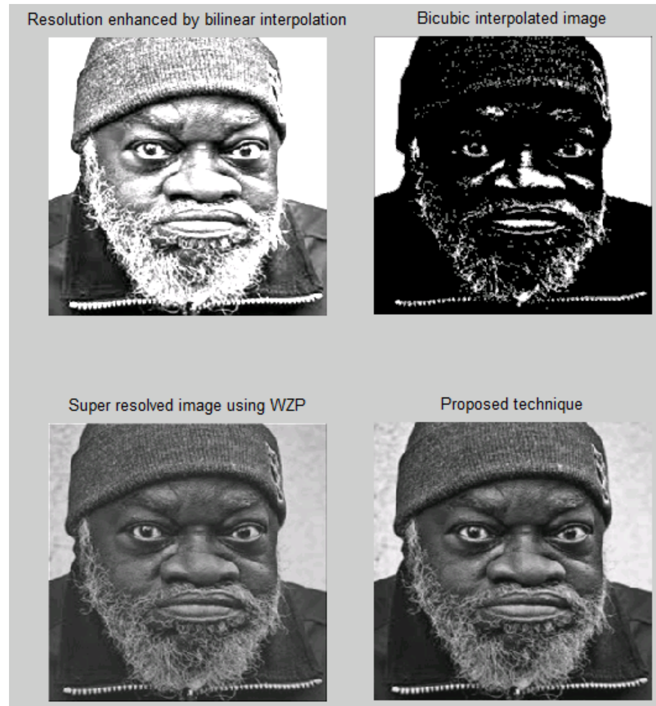

Fig. 5. (a) Original low resolution image. (b) Bicubic interpolated image. (c) Super resolved image using WZP. (d) Proposed technique.

CONCLUSION

This work proposed an 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 input 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 cor rected by using the high frequency sub-bands achieved by SWT of the input image. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency sub-bands. After- wards 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.

TABLE I

Sr. No .	Image Resolution Technique	Peak Signal to Noise Ratio (PSNR)			
		Taj.jpg	Man.jpg	Girl.jpg	Bhakti.jpg

1	Bilinear method	25.1445	28.6419	25.7978	28.5929
2	Bicubic method	27.2008	30.6377	27.8346	30.6239
3	Wavelet zero padding	32.8094	35.4873	33.3148	36.4587
4	Proposed method using DWT and SWT	32.9619	35.9619	33.5382	36.5242

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