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WAVELET ANALYSIS BASED IMAGE SUPER RESOLUTION

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***Abstract*- The increase in demand and performance of personal computing digital image processing is widely being used in many applications. Digital image process has advantage in term of cost, speed and flexibility. The objective is to extract information from the scene is being viewed. Image resolution describes the amount of information contained by images. 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. In this work, an image resolution enhancement technique has been proposed which generates sharper high resolution image. The proposed 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 bi-cubic 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. Although the time and frequency resolution problems are results of a physical phenomenon (the Eisenberg uncertainty principle) and exist regardless of the transform used, it is possible to analyze any signal by using an alternative approach called the multi resolution analysis (MRA).**

Index Terms- Discrete wavelet transform (DWT), stationary wavelet transform (SWT), multi resolution analysis (MRA), Resolution.

I. INTRODUCTION

In this work, an image resolution enhancement technique has been proposed which generates sharper high resolution image. The proposed 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 bi-cubic 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 using inverse DWT (IDWT) to achieve a high resolution output image. [9] The proposed technique has been compared with conventional and state-of-art image resolution enhancement techniques. The conventional techniques used are the following.

(i) Bilinear interpolation
(ii) Bi-cubic interpolation.
(iii) Wavelet zero padding (WZP).

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. Although the time and frequency resolution problems are results of a physical phenomenon (the Eisenberg uncertainty principle) and exist regardless of the transform used, it is possible to analyze any signal by using an alternative approach called the multi resolution analysis (MRA).

MRA, as implied by its name, analyzes the signal at different frequencies with different resolutions. Every spectral component is not resolved equally as was the case in the STFT. MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. [1] This approach makes sense especially when the signal at band has high frequency components for short durations and low frequency components for long durations. Fortunately, the signals that are encountered in practical applications are often of this type. For example, the following figure 1 shows a signal of this type. It has a relatively low frequency component throughout the entire signal and relatively high frequency components for a short duration somewhere around the middle.

II. HISTORY & BACKGROUND

Motivation behind choosing this concept of image super resolution using wavelet analysis is its implausible growth in wide range of applications like biomedical field for diagnosis of many diseases by enhancing the qualities of Dental, chromosome images, CT scan, MRI, PET images. Geostationary satellite image processing for enhancing the quality of captured earth images for identification of various objects like terrestrial area, natural resources.

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.

Image enhancement using wavelet analysis is used in geostationary satellite image processing for enhancing the quality of captured earth images for identification of various objects like terrestrial area, natural resources etc. In Biomedical Field for diagnosis of many diseases by enhancing the qualities of Dental, chromosome images, CT scan, MRI, PET images. As these images are not clear there is a need to enhance them.

Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. You may have noticed that wavelet analysis does not use a time-frequency region, but rather a time-scale region. One major advantage afforded by wavelets is the ability to perform local analysis -- that is, to analyze a localized area of a larger signal [1].

Consider a sinusoidal signal with a small discontinuity -- one so tiny as to be barely visible. Such a signal easily could be generated in the real world, perhaps by a power fluctuation

or a noisy switch. A plot of the Fourier coefficients (as provided by the fft command) of this signal shows nothing particularly interesting: a flat spectrum with two peaks representing a single frequency. However, a plot of wavelet coefficients clearly shows the exact location in time of the discontinuity.

Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques miss, aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. Furthermore, because it affords a different view of data than those presented by traditional techniques, wavelet analysis can often compress or de-noise a signal without appreciable degradation.

Indeed, in their brief history within the signal processing field, wavelets have already proven themselves to be an indispensable addition to the analyst's collection of tools and continue to enjoy a burgeoning popularity today.

A wavelet is a waveform of effectively limited duration that has an average value of zero. Compare wavelets with sine waves, which are the basis of Fourier analysis. Sinusoids do not have limited duration -- they extend from minus to plus infinity. And where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric [3].

Fourier analysis consists of breaking up a signal into sine waves of various frequencies. Similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original wavelet.

Interpolation is the process of using known data to estimate values at unknown locations.

Interpolation method select new pixel from surrounding 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. [3] Unlike other interpolation techniques such as nearest neighbor interpolation and bi-cubic 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.

The bi-cubic algorithm is frequently used for scaling images and video for display. It preserves fine detail better than the common bilinear algorithm. In image processing, bi-cubic interpolation is often chosen over bilinear interpolation or nearest neighbor in image resampling, when speed is not an issue. In contrast to bilinear interpolation, which only takes 4 pixels (2×2) into account, bi-cubic interpolation considers 16 pixels (4×4). Images resampled with bi-cubic interpolation are smoother and have fewer interpolation artifacts. In image resolution enhancement, wavelet transform of a low resolution (LR) image is taken and zero matrices are embedded into the transformed image, by discarding high frequency sub-bands through the inverse wavelet transform and thus high resolution (HR) image is obtained.

III MATHEMATICAL MODEL

In image resolution enhancement by 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 improve 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 means that DWT coefficients are inherently interpolable.

In this, 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 proposed technique, bi-cubic 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 [1].

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. 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. [1] Using input image instead of low frequency sub-band 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, 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. 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 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.

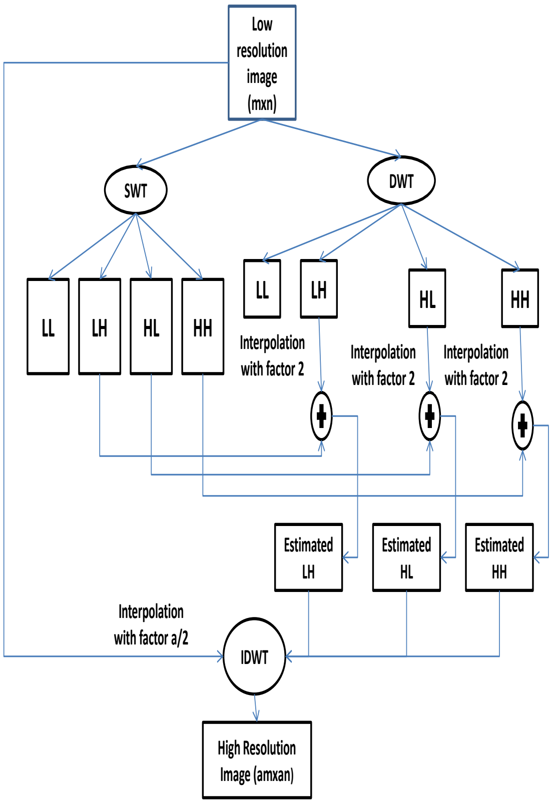

Fig1. Block diagram of the proposed super resolution algorithm

For the purpose of measuring the performance of the techniques quantitative and qualitative metrics is used. For quantitative performance comparison peak signal to noise ratio (PSNR in dB) is often used which is defined

$$PSNR(dB) = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

where MSE is defined as

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left(f(x,y) - \hat{f}(x,y)\right)$$

Digital images have a predominant position among multimedia data types. Unlike video and audio, which are mostly used by the entertainment and news industry, images are central to a wide variety of fields ranging from art history to medicine, including astronomy, oil exploration, and weather forecasting. Digital imagery plays a valuable role in numerous human activities, such as law enforcement, agriculture and forestry management, earth science, urban planning, as well as sports, news casting, and entertainment, Applications of digital imagery are continually developing.

IV . RESULT AND DISCUSSION

(a) (b)

(c) (d)

(e) (f)

	PSNR	MEAN	VARIANCE	STD DEVIATION
Bilinear	28.07	1.03	0.211	0.459
Bi-cubic	30.11	0.004	0.03	0.053
WZP	35.93	0.23	0.0105	0.102
HMM SR	35.82	0.968	0.292	0.5404
CWT SR	27.14	0.968	0.294	0.542
NEDI	35.11	0.379	0.043	0.208
Proposed	35.93	0.23	0.0104	0.102
Propoped & Histogram equalization	43.69	0.49	1.0863	0.293

Fig2. (a) Original image (b) Bi-cubic Interpolated image (c) Bilinear Interpolated image (d) Wavelet zero padding image (e) Proposed technique image (f) Proposed plus histogram equalized image.

Fig.2 shows that super resolved image of Sara picture using proposed technique in (f) are much better than the low resolution image in (a), super resolved image by using the interpolation (b) (c), and WZP (d). 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 image resolution enhancement techniques with different features are used for comparison. Table1 compares the PSNR performance of the proposed technique using bi-cubic interpolation with conventional image resolution enhancement techniques: bilinear, bi-cubic, WZP. The results in Table I indicate that the proposed technique over performs the aforementioned conventional image resolution enhancement techniques. Table 1 also indicates that the proposed technique over-performs the aforementioned conventional image resolution enhancement techniques.

TABLE1 Results for resolution enhancement of the proposed technique compared with the conventional and state-of-the-art image resolution enhancement techniques

V. 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 corrected 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.

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