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# Multiresolution Transforms Based Robust Image Enhancement

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***Abstract:*** *An Image Resolution Enhancement Technique based on Interpolation of the high frequency sub-band of colour images obtained by Discrete Wavelet Transform and the input colour image is proposed in this paper. Interpolation determines the intermediate values on the basis of observed values. One of the commonly used interpolation technique is Bicubic Interpolation. The edges are enhanced by introducing an intermediate stage by using Stationary Wavelet Transform. It is designed to overcome the lack of Translation-Invariance of Discrete Wavelet Transform. This is widely used in Signal Denoising and Pattern Recognition. Discrete Wavelet Transform is applied in order to decompose an input colour image into different sub-bands. Then the high frequency sub-bands as well as the input colour image are interpolated separately. The interpolated high frequency sub-bands and the Stationary Wavelet Transform 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. Then all these sub-bands are combined with interpolated input image for new high resolution image by using Inverse Discrete Wavelet Transform. This has been done by MATLAB. The Peak Signal-Noise Ratio was obtained up to 5dB greater than the conventional and state-of-art image resolution enhancement techniques.*

***Key words:*** *Discrete Wavelet Transform, Image Super Resolution, Stationary Wavelet Transform.*

## I. Introduction

Resolution has been referred as an important aspect of an image. One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation in image processing is a method to increase the number of pixels in a digital image. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple description coding, and super resolution. Bicubic interpolation is more sophisticated than the other two techniques such as Bilinear and Nearest Neighbour interpolation. Image resolution enhancement in the wavelet domain is a relatively new research addition and recently many new algorithms have been proposed.

Discrete wavelet transform (DWT) is one of the recent wavelet transforms used in image processing. Another recent wavelet transform which has been used in several image processing applications is stationary wavelet transform (SWT). The high frequency sub-bands obtained by SWT of the input image are corrected by the interpolated high frequency sub-bands of DWT to obtain the estimated co-efficients. In parallel, the input image is also interpolated separately. Finally applying inverse DWT (IDWT) to the estimated coefficients and interpolated input image a high resolution image is obtained. This work proposes an image resolution enhancement technique which generates sharper high resolution image.

This paper is organized as follows. Section II addresses the various techniques for resolution enhancement. Section III explains about the proposed technique for resolution enhancement of colour images. Section IV describes the results and discussion and Section V summaries the conclusion.

## II. Literature Review

Several research papers and reports were addressed the subject of resolution enhancement and PSNR improvement of an image by using several Image Resolution Enhancement Techniques and Algorithms.

Ammu and Kamatchi (2013) [1] has investigated the satellite image resolution and brightness enhancement technique based on the discrete wavelet transform (DWT) and singular value decomposition (SVD). The PSNR improvement was found to be up to 7.19 dB as compared with the standard bilinear interpolation. Brian Atkinst et al (2001) [2] had introduced a Resolution Synthesis (RS) approach to optimal image scaling. Hasan Demirel and Gholamreza (2010) were discussed about enhancement technique based on Dual Tree-Complex Wavelet Transform [3] for resolution enhancement of grayscale images.

W. Knox Carey (1997) [4] had designed the Regularity-Preserving Interpolation method to synthesizes a new wavelet sub-band based on the decay of the known transform co-efficients. This algorithm provides the value of 2.5dB over traditional methods. YinjiPia (2007) [5] were introduced an Inter-Subband Correlation in which the sampling phase in DWT is considered for image enhancement. Compared to conventional techniques it provides the PSNR value as much as 0.38dB, but time consuming is less. Alptekin Temizel (2007) [6] has described a Hidden Markov Tree (HMT) based methods using Gaussian mixture models to estimate the unknown detail coefficients. This method provided only 50% of accurate sign estimation when compared to other conventional techniques. Alptekin Temizel, Theo Vlachos (2006) [7] were discussed the wavelet domain image resolution enhancement algorithm for image resolution enhancement.

G.Anbarjafari and H.Demirel (2010) [8] proposed a new super-resolution technique called Demirel-Anbarjafari Super Resolution (DASR) is based on interpolation of the high-frequency subband images obtained by discrete wavelet transform (DWT) and the input image, which generates sharper super resolved images by means of providing PSNR value of 5.43dB when compared to other techniques. G.Anbarjafari and H.Demirel (2011) [9] had discussed combination of both DWT and SWT for resolution enhancement of grayscale images. But this technique produces the PSNR with maximum value of 35.01dB only. Guoliang Fan and Xiang-Gen Xia1 (2000) [10] have presented a Wavelet-Domain Hidden Markov Tree (HMT) model for image denoising and segmentation. By this method image denoising performance can be improved only up to 0.4-0.9dB. Liyakathunisa and Ravi Kumar (2011) [11] had discussed DCT based progressive image display algorithm by stressing on the encoding and decoding process for the problem of recovering a high resolution image progressively from a sequence of low resolution compressed images. Li Yi-bo (2007) [12] proposed a Wrinkle Generation Method for Facial Reconstruction based on extraction of partition wrinkle line features and fractal interpolation.

M. El-Sayed Wahed (2007) [13] were introduced the development of algorithms based on second generation wavelets for super resolution (SGWSR) with the capability of simultaneous noise reduction. Nicola Asuni and Andrea Giachetti (2008) [14] had described an Improved New Edge Directed Interpolation (iNEDI) instead of well-known NEDI. The interpolation quality scores obtained with this iNEDI algorithm are notably higher than those obtained with NEDI. Osama A. Omer (2012) [15] proposed a Segmentation-Based Optical Flow Estimation technique for motion estimation with a modified model for frame alignment. The proposed algorithm gave promising results for low resolution sequences with slow/fast motion.

## III. Proposed Image Resolution Enhancement

The proposed technique uses DWT to decompose a colour image into different sub-bands, and then this subband image have been interpolated. The interpolated high frequency sub-band co-efficients have been corrected by using the high frequency subbands achieved by SWT of the input colour image. An original colour image is interpolated with half of the interpolation factor used for interpolating the high frequency subbands. Afterwards all these, colour images have been combined using IDWT to generate a super resolved images.

### 3.1 Interpolation

There are three well-known interpolation techniques; namely, Nearest Neighbour Interpolation, Bilinear Interpolation, and Bicubic Interpolation. Bicubic interpolation is more sophisticated than the other two techniques but produces smoother edges than bilinear interpolation. In this proposed system Bicubic Interpolation is used in order to interpolating the data points on a two dimensional regular grid.

### 3.2 Discrete Wavelet Transform

Wavelet transform decomposes a signal into a set of basic functions. These basis functions are called *wavelets.* Wavelets are obtained from a single prototype wavelet called mother *wavelet* by *dilations* and *shifting.*

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (1)$$

Where, *a* is the scaling parameter and *b* is the shifting parameter.

The drawback of Continuous Wavelet Transform (CWT) is little expensive & generates redundant data at computation time. In order to overcome this drawback, an effective transformation called (Discrete Wavelet Transform) DWT is used. It can be expressed as,

$$W_{a,b} = \int_{-\infty}^{\infty} x(t)\,\psi(t)dt \qquad (2)$$

Where, $W_{a,b}$is Discrete wavelet transform, $x(t)$is input signal and $\psi(t)$is mother wavelet.Theoretically, a filter bank shown in Fig.1 should work on the input colour image in order to generate different sub-band frequency images.

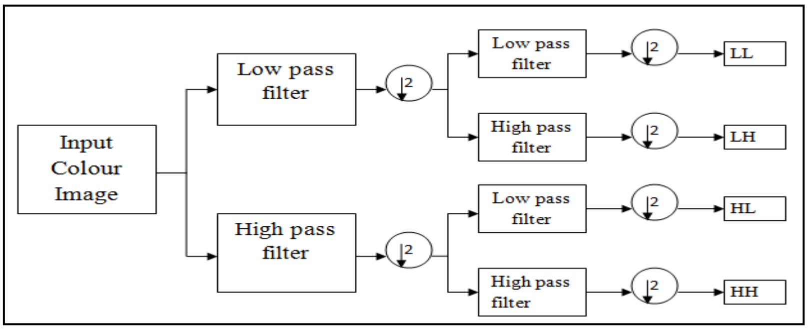


**Fig.1 Block diagram of DWT Filter Banks of level 1**

Discrete wavelet transform (DWT), transforms a discrete time signal to a discrete wavelet representation. It has been formulated using Filters of different cut-off frequencies, say Low-pass filter to analyze low frequencies (called 'approximation') & High-pass filter to analyze high frequencies (called 'detailing'). So that one can have an error free signal. For decomposition of an input color image 'Multiresolution Decomposition' (MSD) technique can be used by downsampling. This technique providing an advantage of low processing time.DWT produce four subbands low-low (LL), low-high (LH), high-low (HL) and high-high (HH). The original image can be regenerated by using four subbands.

**3.3 Stationary Wavelet Transform**

The Stationary wavelet transform is a wavelet transform algorithm which is created to remove lack of translation-invariance of discrete wavelet transform (DWT). The SWT is ambiguous scheme as output of each level of SWT contains same number of samples as that of input, so for decomposition of N levels there is ambiguity of N in the wavelet coefficients. SWT also known as undecimated wavelet transform is similar to that of DWT just the size of subbands produced by SWT is same as that of input image size because it not use downsampling as it is used in DWT. Fig.2 illustrates the Block diagram of SWT Filter Banks of level 1. 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.

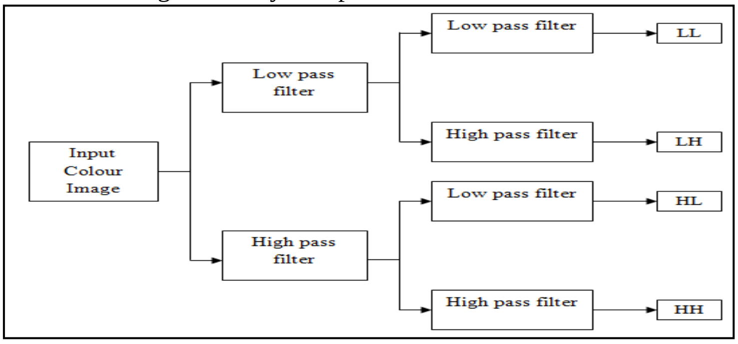


**Fig.2 Block diagram of SWT Filter Banks of level.1**

Downsampling in each of the DWT subbands causes information loss in the respective subbands. That is why SWT is employed to minimize this loss. 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.

Fig.3 illustrates the block diagram of the proposed image resolution enhancement technique. By interpolating input image by $\alpha/2$, and high frequency sub-bands by 2 and $\alpha$ 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.

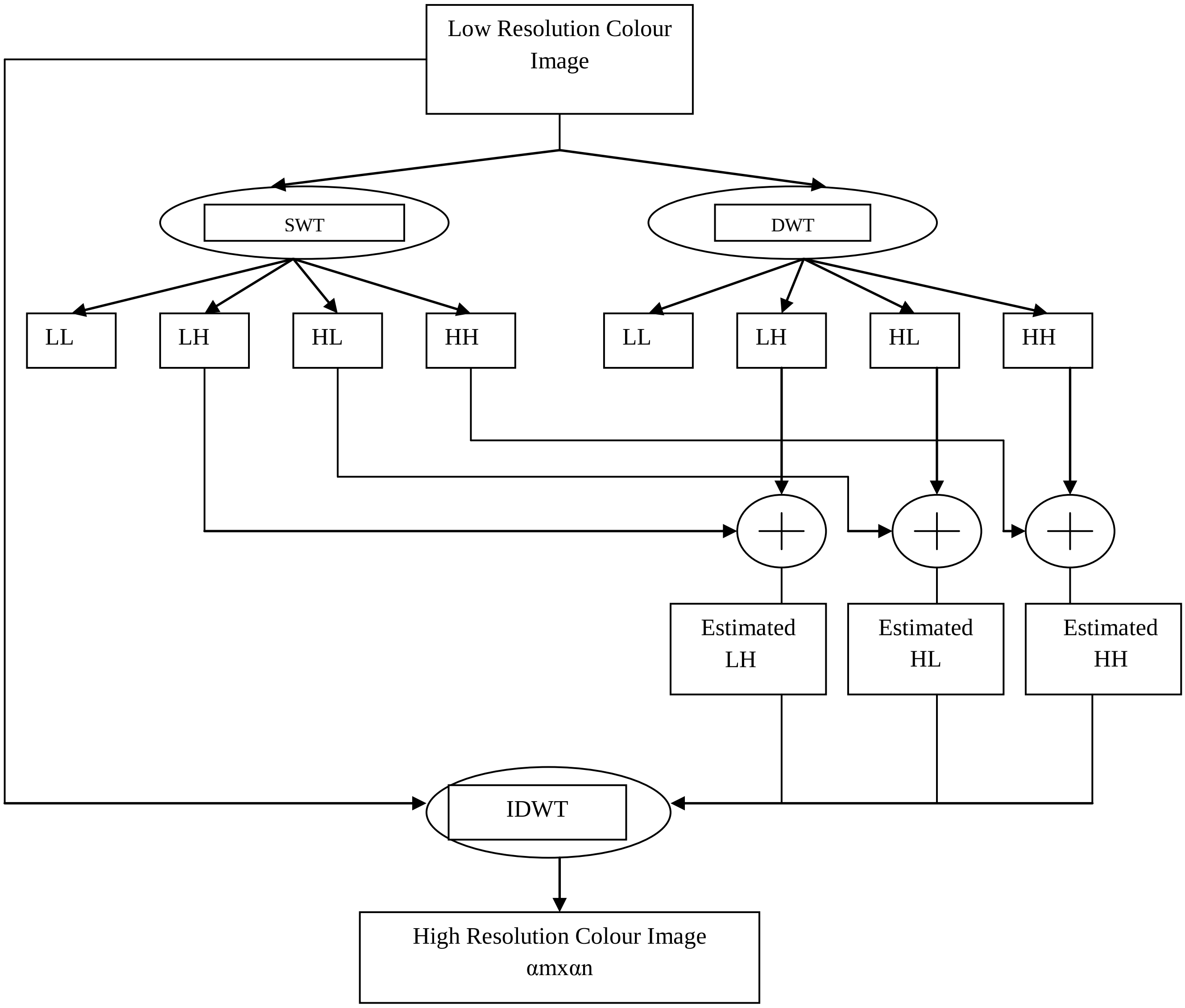


**Fig.3 Block Diagram DWT and SWT based Image Resolution Enhancement**

## IV. Results And Discussion

The resolution of an image can be calculated by using Peak Signal to Noise Ratio (PSNR) is given by,

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) \qquad (3)$$

This equation can also be written as,

$$PSNR = 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \qquad (4)$$

Where, $MAX_I$ is the maximum possible pixel value of the image. MSE is Mean Squared Error.

Each of the three-colour components (RGB) is a matrix that is decomposed using the two-dimensional wavelet decomposition scheme such as, SWT and DWT. An RGB image sometimes referred to as a true colour image, is stored in MATLAB that defines red, green, and blue colour components for each individual pixel. This type of RGB image is not suitable for direct wavelet decomposition. So that the colour indexed image is separated into its RGB components. Generally low resolution RGB image is taken as input that is applied for wavelet decomposition schemes such as, DWT and SWT.

Fig.5. (a) original low resolution lena's image. (b) DWT applied image for red component. (c) SWT applied image for red component. (d) Adding horizontal component of DWT and SWT. (e) Adding vertical component of DWT and SWT. (f) Adding diagonal component of DWT and SWT.

(a) Input Image

(b) DWT Applied Image

(c) DWT Applied Image

(d) Addition of Horizontal Component

(e) Addition of Vertical Component

(f) Addition of Diagonal Component

**Fig.5 Lena's Image**

Before applying wavelet decomposition the input RGB image is separated in to red, green and blue components. DWT and SWT are applied for each colour component individually. Then by using Bicubic interpolation, the frequency subbands obtained from DWT is interpolated and then subbands from both wavelet are added by means of horizontal, vertical and diagonal manner. Similarly DWT and SWT are applied for both green and blue component and their corresponding components are added to each other. Finally Inverse DWT is applied in order to obtain the high resolved image. This result indicates that the proposed technique over-performs the aforementioned conventional and state-of-art image resolution enhancement techniques.

**Table 1. PSNR (dB) results for resolution enhancement of the proposed technique compared with the conventional and state-of-art image resolution enhancement techniques for lena's and baboon's image.**

| | PSNR[dB] | |
|---|---|---|
| **Techniques/Images** | **Lena** | **Baboon** |
| Bilinear | 29.28 | 27.71 |
| Bicubic | 31.30 | 29.69 |
| WZP | 36.28 | 34.81 |
| DWT and SWT for grayscale image | 36.74 | 34.98 |
| Proposed technique | 40 | 38 |

Table 1 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-CSER, DWT SR, CWT SR, and regularity-preserving image. When compared to PSNR value obtained by the bicubic interpolation for gray scale image, the proposed technique produces 9dB greater value for colour image. DWT and SWT for colour image produces 5dB greater PSNR value when compared to gray scale image.

## V. Conclusion

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency sub-bands obtained by DWT and also established the correction of 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. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. The visual result of the proposed technique shows that the PSNR improved upto 5dB when compared to conventional techniques.

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