Enhancement of Image Resolution by Using Surface Fitting & SWT

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***Abstract* - This paper presents an image resolution enhancement technique which is based on surface fitting of the high frequency components in an image obtained by Discrete Wavelet Transform (DWT) of an image and enhanced by using Stationary Wavelet Transform (SWT) of an image at intermediate stage of Process. The high frequency sub-bands component of an image were filtered by using DWT & interpolated using surface fitting. These frequency sub-bands modified by high frequency Sub-bands obtained through SWT. The output image will generated through Inverse discrete Wavelet Transform (IDWT) and interpolated with input image by surface fitting and high frequency sub-bands Component. The qualitative and quantitative better results show the effectiveness of this Modified method over other standard image resolution Enhancement techniques.**

Index Terms— Image Super-resolution; Gaussian Noise; Discrete Wavelet Transformation; Stationary Wavelet Transformation; surface fitting.

I. INTRODUCTION

Digital Image super-resolution is required because of the limitation and short-comings of the image acquisition device/systems and/or possibly ill-posed acquisition conditions. The purpose of image super-re solution is to produce a high resolution image based on a set of image of same scene or from a single image. With rapid development image processing for visual communication there is high demand for high resolution images and videos. There are various image super-resolution techniques such as Frequency domain based, Interpolation based, Regularization-based and learning based. There are various interpolation methods such as nearest neighbor bilinear, bicubic interpolation. The idea of image super-resolution using wavelet domain is relatively new, many algorithms have been proposed [1] [2] [3] [4] in this domain. DWT [5] 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) [6]. 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.

In this paper we proposed a method to enhance the resolution of the image results into a high resolution image (RR). In this method high frequency components of low resolution image (LR) are generated using DWT transform as proposed [1 4]. The se high frequency components have been interpolated using surface fitting interpolation method [7] .Then the interpolated high frequency components are adjusted by adding high frequency components generated using SWT. The low resolution image is interpolated using surface fitting in parallel. After that the high resolution image is generated by combining interpolated image and interpolated high frequency components using Inverse DWT (IDWT) .

This proposed method is compared to various conventional and state-of-art techniques of image interpolation. After comparing the results, although this method outperforms some of the methods but give s comparable results to some of the other methods. Rest of the paper is organized as follows. Section 2 describes the proposed method and the experimental results are shown in Section 3 followed by conclusion.

II. PROPOSED METHOD

The idea is that the DWT coefficients are interpolable [6] , so the high frequency components of LR image can be interpolated in order to preserve the high frequency components of the RR image. Normal interpolation method smoothens the high frequency components of LR image with other components, hence it causes the loss of high frequency components (i .e. edge s). To preserve the quality of the image the high frequency components are essential.

In this method, 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) contains the horizontal vertical and diagonal details of the input image. In the proposed technique, surface fitting [7] is applied to high frequency sub-bands of the LR images, then size of each high frequency sub-band is doubled using row and column duplication. 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 as given in [1 4] . The corrected DWT high frequency sub- bands again interpolated using surface fitting. Instead of low frequency components of low resolution image, we have used interpolated image in IDWT . The interpolated image and interpolated high frequency DWT components supplied to IDWT to generate a HR image.

Interpolating the high frequency sub-bands by factor 2 in intermediate stage and the low resolution image preserves the low frequency details of the LR image. The HR image is generated by applying IDWT on interpolated LR image and interpolated high frequency DWT sub-bands. The interpolation of each high frequency DWT sub-bands with correction using high frequency SWT sub-bands preserves more high frequency components than directly interpolating the image, thus the output HR image has sharper edge s. The algorithm of proposed method is given as follows.

A. SR Algorithm

Given low resolution image LR.

- Generate different frequency sub-bands using DWT with wavelet function Daubechies 9/7 .
  [LL, LH, HL, HH] = DWT (LR)
- Generate different frequency sub-bands using SWT with wavelet function Daubechies 9/7 .
  [LLl, LH l, HL I, HH l] = SWT (LR)
- interpolate DWT high frequency sub-bands using
  surface fitting by fa ctor 2
  I_LH = surface_fit(LH)
  I_HL = surface_fit(HL)
  I_HH = surface_fit(HH)
- adjust the interpolated DWT high frequency subbands by adding SWT high frequency sub-bands
  I LH = I LH + LH I
  I HL =I HL + HL I
  I HH = I HH + HH I
- further interp olate DWT sub-bands using surface fitting by fa ctor p .
  F _ LH = surface _ fit(1 _ LH)
  F _ HL = surface _ fit(1 _ HL)
  F _ HH = surface _ fit(1 _ HH)
- interpolate input low re solution image using surface fitting
  Img = surface_fit(LR)
- generate high resolution image HR using interpolated image (Img) and interpolated
  Sub-bands (F _LH, F _HL, F _HH).
  HR = IDWT(lmg, F _LH, F _HL, F _HH)

B. Surface Fitting Based interpolation

The concept of surface fitting uses the spatial structure information of the image. The interpolation is done by constructing a surface on each low resolution pixel. We have used the idea of Fei Zhou et. al. [7] with manipulation. Only one low resolution image is used as input and the fmal estimation is done by adding various λ values instead of MAP estimation. Multisampling is not required as we are using only a single image as input for the interpolation.

The surface fitting based interpolation is applied on various high frequency sub-bands obtained by DWT of input low resolution image. This interpolation is used at the intermediate step of the proposed algorithm. Fig. 1 shows the block diagram of proposed method.

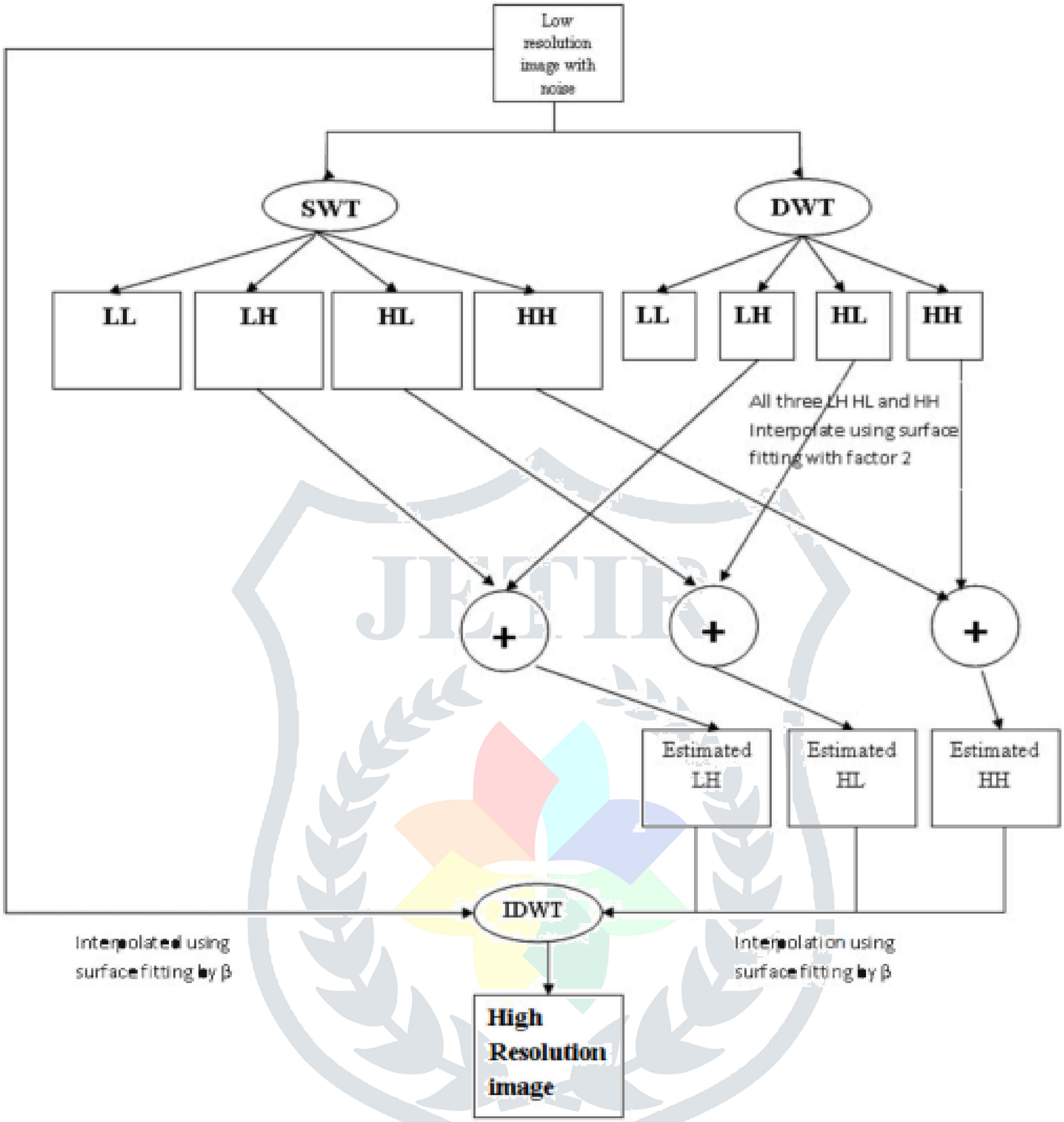

Fig-1 Block Diagram of proposed method

III. **EXPERIMENTAL RESULTS**

To demonstrate the performance of this method, the results were compared with conventional interpolation methods (bilinear and bicubic) and some of the state -of-art interpolation methods [2] [4] [8] [9] [10] [11] [12] [13] [14]. All the codes were written in MATLAB and executed on Intel 32 bit Architecture with Intel core2 duo 2.00 GHz machine. Simulation is carried out on four well known images Lena, Baboon, Peppers and Elaine as shown in Fig. 2 (a)-(d) . These images were taken from USC- SIPI image database [15] and the resolution of all images is 51 2x5 12.

In our simulation, the images were corrupted by Gaussian noise with signal-to noise ratio (SNR) of 15 dB and 10 dB . The low resolution images were generated by fourfold down sampling of original HR images.

A. Experiment 1 : SR Reconstruction of Well Known Images In order to quantify the results peak signal -to-noise ratio (PSNR) is used. Higher the PSNR values better the results of interpolation. The PSNR value is given by (1)

B.

$$PSNR = 10log_{10}\left(\frac{255^2}{MeanSquareError}\right) \dots \dots (1)$$

The quantitative comparison of our method with other methods is given in TABLE I.

Fig. 2. Original images that is tested (a) Elaine (b) Baboon (c) Lena (d) Peppers

our method gives better results than other methods. Moreover previous methods did not consider noise in the LR images, but we have taken noisy images into account. For Baboon image our method give s better results from all the methods and the results of our method for Pepper image are also good from all the methods and comparable to DWT and SWT [1 4] . For Lena and Elaine images results of our method are comparable to all other methods because we have interpolated noisy input images. The visual results of the well-known images with noise (15 dB) are shown in Fig. 3.

In addition to PSNR, another metric, known as visual information fidelity (VIF) [16], is attractive for image quality assessments. In [16], this metric is reported to be consistent with subjective human evaluation. A larger VIF means a better result of reconstruction. If VIF reaches 1, the "perfect" reconstruction is achieved. The VIF index of all the output HR images generated using proposed method is provided in Table II

C. Experiment 2: SR Reconstruction of Real World Image

In this section the proposed method was tested on a real world image. A real world image of flower was taken using Nikon coolpix camera shown in Fig. 4(a). This image was taken as ground truth image. The LR image (Fig. 4(c)) was generated from the captured image and the HR image using the proposed method. The visual result is shown in Fig. 4(b) .

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

Techniques/ Images	PSNR (DB)			
	Baboon	*Peppers*	*Elaine*	*Lena*
Bilinear	20.51	25.16	25.38	26.34
Bicubic	20.61	25.66	28.93	28.86
WZP (db. 9/7)	21.47	29.57	30.44	28.84
Regularity Preserving Interpolation [4]	21.47	29.57	30.42	28.81
NEDI [8]	21.18	28.52	29.97	28.81
HMM [9]	21.47	29.58	30.46	28.86
HMM SR [10]	21.49	29.60	30.51	28.88
WZP-CS [11]	21.54	29.87	30.78	29.27
WZP-CS-ER [12]	21.56	30.05	30.89	29.36
DWT SR [13]	23.29	32.19	32.73	34.74
CWT SR [2]	23.12	31.03	33.05	33.74
SWT SR	23.74	29.46	31.25	32.01
DWT and SWT (db9/7) [14]	23.87	33.06	35.01	34.82
Proposed with noise (15 db)	27.26	33.31	34.35	33.23
Proposed with noise (10 db)	26.47	32.08	32.66	32.09

Quantitative and qualitative results are shown in Table III .

IV. CONCLUSION

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency sub-bands obtained by DWT, correcting the sub-bands estimation by using SWT high frequency sub-bands, and the input image. The proposed technique used DWT to decompose an image into different sub-bands and then the high frequency DWT sub-bands images have been interpolated. The interpolated high frequency sub-bands coefficients have been corrected by using the high frequency sub-bands achieved by SWT of the input image. An original image was interpolated with half of the interpolation factor used for interpolation the low frequency sub -bands. Further all the se images have been combined using IDWT to generate a super resolved image. The proposed technique have been tested on well-known benchmark image s, where their PSNR and visual results shows the comparison of proposed technique with the conventional and state -of-art image re solution methods.

Fig. 3. (a) Input LR image 128x I28 (b) Output HR image 5I2x5I2

TABLE II. VIF INDEX FOR ALL FOUR IMAGES

Images/Noise (db)	VISUAL IMAGE FIDELITY INDEX	
	SNR 15 (db)	*SNR 10 (db)*
Baboon	0.3927	0.1546
Peppers	0.4974	0.1497
Elaine	0.4923	0.1264
Lena	0.5698	0.1438

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