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Image Resolution Enhancement by Wavelet Transform Based Interpolation and Image Fusion

Neha Tripathi
Dept. of Electronics & Comm. Engg.
SATI, Vidisha, M.P., India

Asst. Prof. Krishna Gopal Kirar
Dept. of Electronics & Instru. Engg.
SATI, Vidisha, M.P., India

***Abstract*— This paper presents a resolution method for enhancing digital gray images. The proposed enhancement technique is based on the interpolation of the high frequency sub-bands obtained by DWT and SWT. 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. The lower sub band obtained by DWT decomposition is interpolated with the same interpolation factor. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. Further we have made up extra enhancement in the image with the help of the fusion.**

***Keywords*— Image Super Resolution, Interpolation, Discrete Wavelet Transform and Stationary Wavelet Transform, Image Fusion.**

I. INTRODUCTION

The objective of image Resolution enhancement is to overcome the limitation of the image acquisition device or ill posed acquisition condition [1]. A Super Resolved image is useful for many fields. Resolution has been frequently referred as an important property of an image whether it's a satellite image or a medical image. These days satellite images are being used in different fields, so it is essential to have high resolution satellite images [1-2]. These images are affected by various factors such as absorption, scattering etc in the space. To have better perception of these images it is necessary to increase the resolution. Resolution enhancements of these images have always been a major issue to extract more information from them. Similarly the Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical field. Enhanced medical images are desired by a radiologist to assist diagnosis and interpretation because medical image qualities are deteriorated by noise and other data acquisition devices, illumination conditions, etc. Also targets of medical image enhancement are mainly to solve problems of low contrast and the high level noise of a medical image. Medical image Enhancement technologies have attracted so many new studies [4-5]. Images are being processed in order to obtain super enhanced resolution. 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 [4], multiple description coding [5], and image resolution enhancement [6]–[8]. The interpolation-based image resolution enhancement has been used for a long time and many interpolation techniques have been developed to increase the quality of this task. There are three well-known interpolation techniques, namely, nearest neighbor, bilinear, and bicubic. Bicubic interpolation is more sophisticated than the other two techniques and produces smoother edges.

The drawback of interpolation method is that, this method cannot do super resolution of single image since it cannot produce those high-frequency components that were lost during the image acquisition process. G. Anbarjafari and H. Demirel proposed a new technique for image Super Resolution by combining both the wavelet transform and interpolation. This technique reduces all the drawbacks of above mentioned techniques. However, applying interpolation in high frequency sub-bands introduces aliasing effects [10, 11]. The proposed technique also combines the wavelet transform and interpolation. This method uses stationary wavelet transform instead of discrete wavelet transform. The proposed method is tested with different types of wavelets & interpolation methods & results are compared.

II. BACKGROUND

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. Hasan Demirel and Gholamreza Anberjafri proposed a method, in this method; 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. One level DWT is used to decompose an input image into different sub-bands**.**

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. Down sampling 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.

Fig. 1 illustrates the block diagram of the Image Resolution by using Discrete and Stationary Wavelet Decomposition technique. By interpolating input image by α/2, and high frequency subbands by 2 and α in the intermediate and final interpolation stages respectively, and then by applying IDWT, 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.

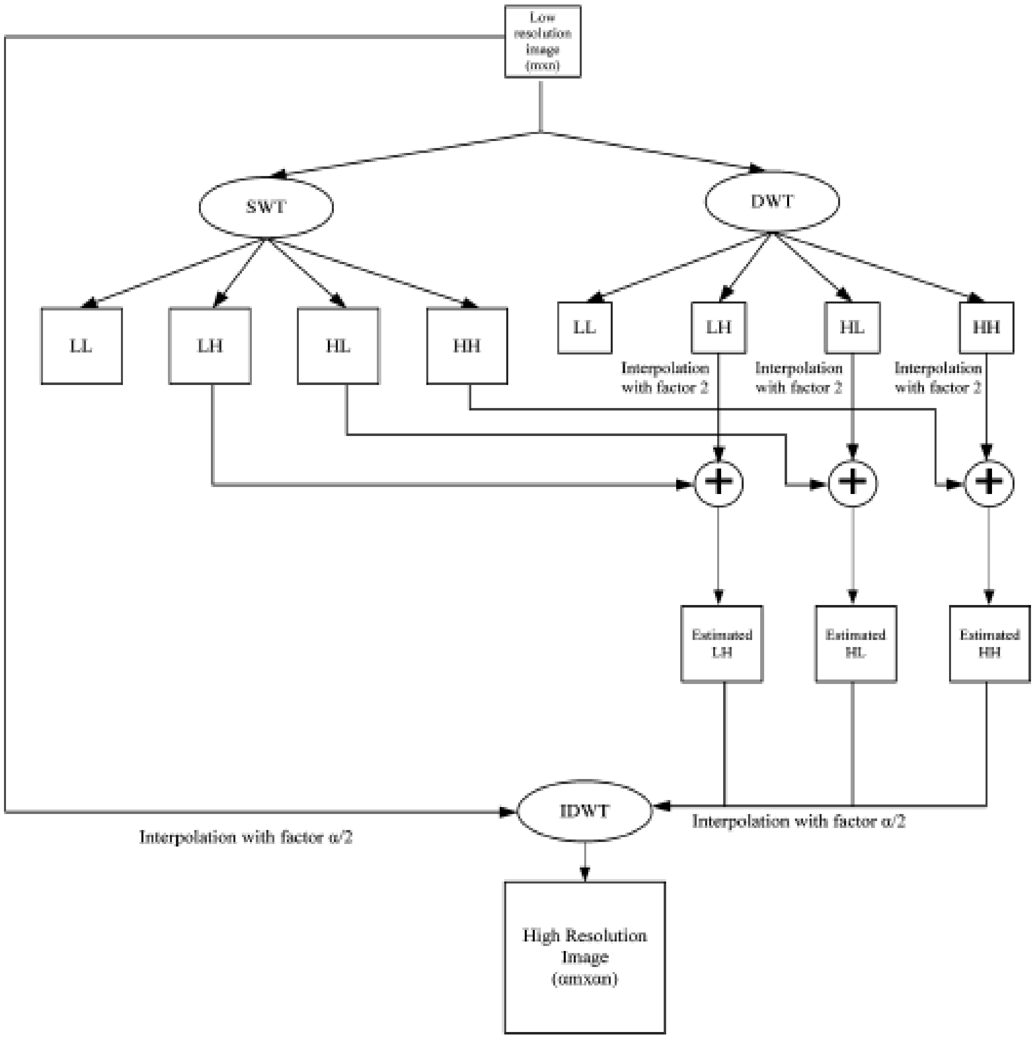


Fig. 1. Image resolution enhancement using the DWT and SWT based method.

III. PROPOSED METHODOLOGY

In the above method lower component are ignored but this method considered higher component as well as lower component. Thus the Proposed methodology follows the following steps:

1. In the first step, an input low resolution image is generated from original high resolution image through Gaussian down sample function. In this function firstly the original high resolution image is passed through a Gaussian low pass filter, which passes only low frequency component of image. The image is then down sampled row and column wise by a factor of 2. This converts the original high resolution image of size 512×512 into low resolution image of size 128× 128.
2. In the second step, Discrete Wavelet Transform (DWT) and SWT is applied to the input low resolution image in parallel. The input low resolution image is decomposed through the DWT and SWT in four sub bands represented by LL (low-low), LH (low-high), HL (high-low) and HH (high-high) each. For the SWT the sub bands have the size that of the input image whereas for the DWT, after the decomposition the sub bands have the smaller size.
3. Now the Higher sub bands of DWT are interpolated by a factor of 2 and added with the corresponding higher subbands obtained through the SWT decomposition. The resultant components are interpolated by a factor of α/2 to generate the estimated LH, HL, and HH.

4. Lower sub band obtained through the DWT decomposition is interpolated with a factor of α to generate the estimated LL component.
5. Estimated LL, LH, HL and HH component are combined using the Inverse Discrete Wavelet Transform (IDWT) to provide the higher resolution image.
6. The obtained image is fused with the interpolated original image by a factor of alpha. The fusion is done by taking the maximum value component in the wavelet domain.

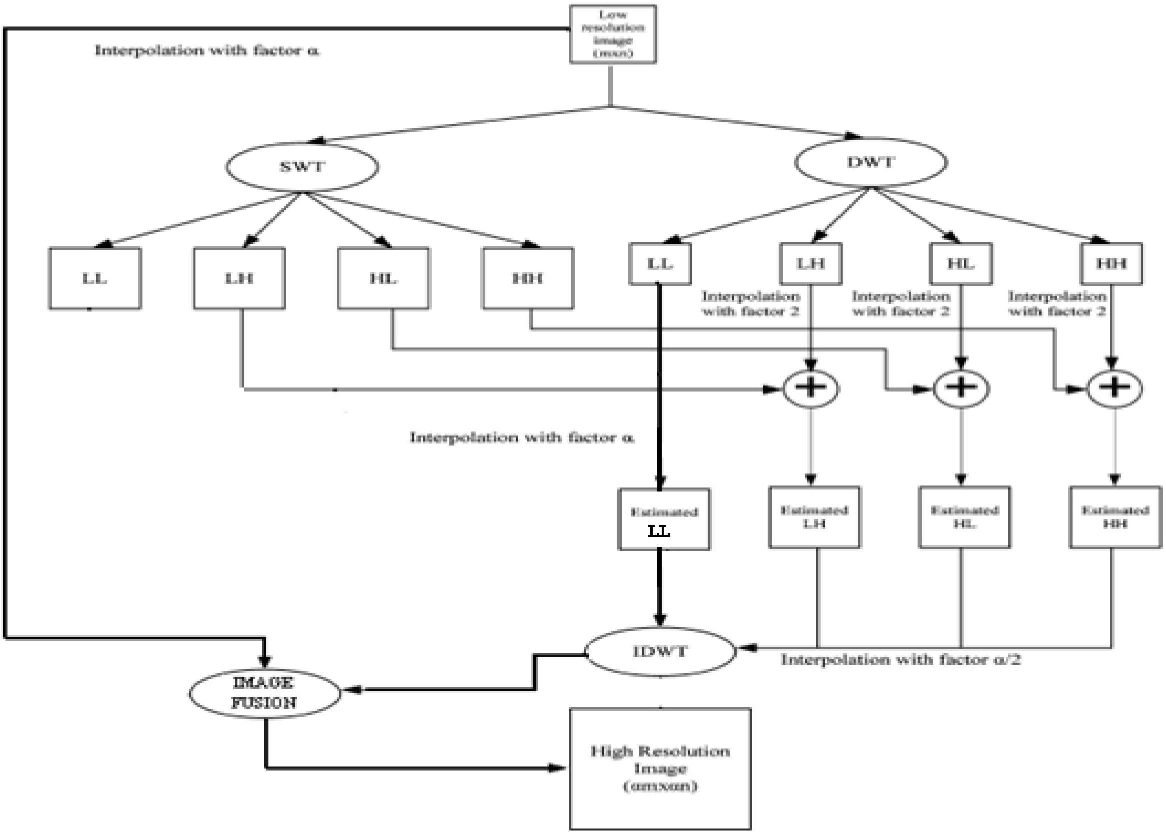


Fig. 2. Image resolution enhancement using the proposed method.

a) PERFORMANCE PARAMETERS

1) MSE and PSNR: Techniques commonly employed for image compression result in some degradation of the reconstructed image. A widely used measure of reconstructed image fidelity for an N *x M* size image is the mean square error (MSE) and is given by -:

$$MSE = \frac{1}{M.N}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left|f(i,j) - \hat{f}(i,j)\right|^2$$

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

2) STRUCTURAL SIMILARITY (SSIM) INDEX

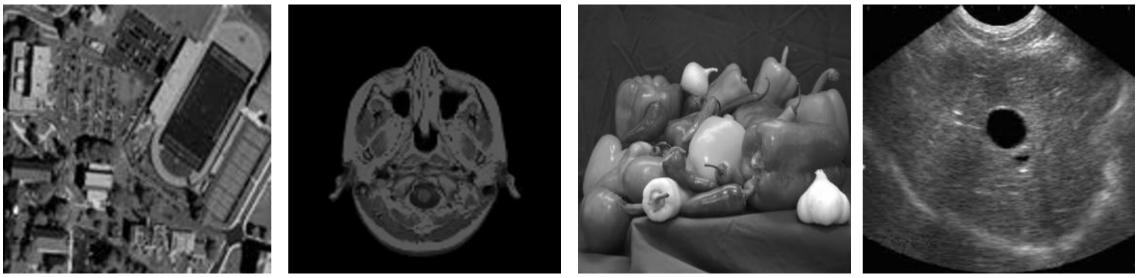
The structural similarity (SSIM) index is a method for measuring the similarity between two images. SSIM considers image degradation as perceived change in structural information.

$$\text{SSIM}(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

Here μ_x and μ_y is the mean value of the image x and image y. σ_x and σ_y Are the varience of the image x and y respectively. σ_{xy} Is the covariance of x and y image.

b) RESULTS AND DISSCUSSION

The performance of the proposed super resolution method is tested on four gray scale images shown in Fig. 3. Firstly these images are converted into their low resolution image through Gaussian down sample function and then DWT and SWT is applied to the low resolution image. The performance of the proposed method is compared by applying wavelets namely Haar, Db8, Sym4 and Sym8. Table 1 shows the results of the DWT and SWT based method and Table 2 shows the results of the proposed method for different wavelets in terms of PSNR and SSIM. It is clear from comparison the PSNR and SSIM of super resolution Image of proposed method is better as compare to DWT and SWT method.



(a) (b) (c) (d)

Fig.3. (a), (b), (c), (d) Test images.

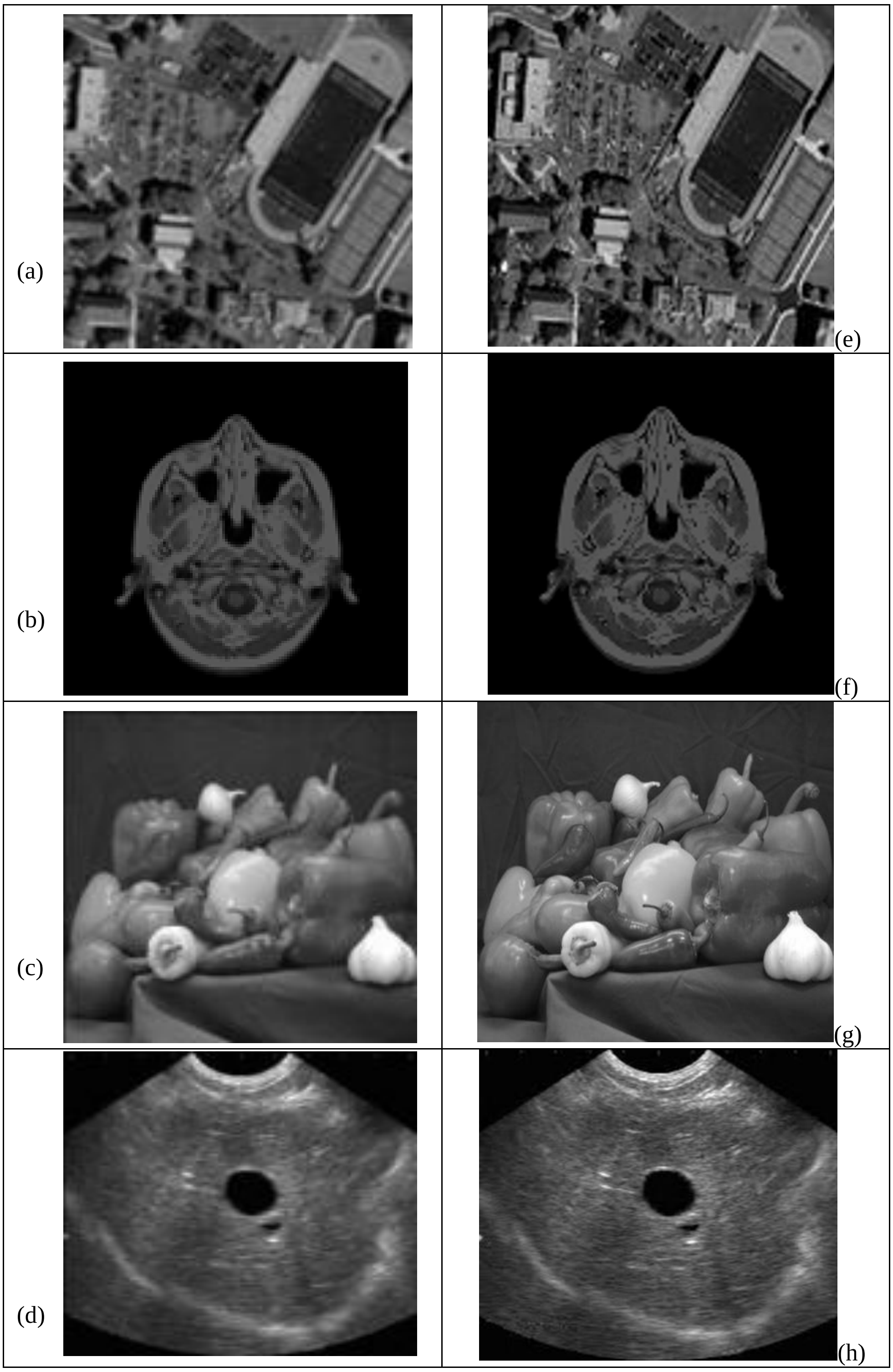


Fig. 4. (a), (b), (c), (d) Low resolution images and (e), (f), (g), (h) High resolution images obtained by the proposed method.

Table 1. Results of the DWT - SWT based method

Wavelet name	Satellite image		mri.tif		peppers		Ultrasound image	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Haar	14.318	0.327	21.635	0.366	14.405	0.362	15.941	0.347
Db8	14.543	0.324	21.878	0.364	14.551	0.361	16.043	0.345
Sym4	14.493	0.322	21.834	0.363	14.533	0.361	16.019	0.343
Sym8	14.550	0.324	21.880	0.364	14.549	0.362	16.042	0.345

Table 2. Results of the proposed method

Wavelet name	Satellite image		mri.tif		peppers		Ultrasound image	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Haar	25.629	0.913	33.330	0.972	29.287	0.967	29.301	0.957
Db8	16.979	0.493	25.374	0.843	20.380	0.794	21.348	0.765
Sym4	20.193	0.726	29.687	0.937	23.336	0.875	26.223	0.915
Sym8	17.872	0.559	27.872	0.907	20.708	0.787	23.304	0.845

IV. CONCLUSION

We have seen the significance and requirement of the image resolution enhancement. We have studied the DWT-SWT based method of image resolution enhancement. We have analyzed the problem associated with these method and proposed a different technique for the same. Further implemented this technique and finally we compared with proposed method on the basis of the parameters i.e. PSNR and SSIM. All the results are shown in the tabular form. From the results, found that proposed technique significantly better than the other techniques. The proposed method works good for both satellite and medical image. Thus it’s a better technique for both the applications. We may utilize this for the enhancement of other poor resolution images also.

In the future, we may try to get some technique which provides more improvement in the PSNR and the SSIM, to get the super resolution images.

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