Image Super Resolution based on Discrete and Stationary Wavelet Transform Using Canny Edge Extraction and Non Local Mean

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Abstract—: **This paper addresses the issue of generating a high-resolution(HR) image from single low quality or low-resolution(LR) image. In this work, Discrete wavelet transform (DWT) is used with the Stationary wavelet transform (SWT) to generate or increase the resolution of the image. SWT reduces the translation invariance presence in DWT. To preserve the edges Canny edge extraction is used to get the sharper image. To interpolate the image into the intermediary stage of proposed algorithm Lanczos interpolation is used and to reduce the artifacts introduced by the DWT Non-local mean(NLM) filter has been used. The experimental result shows that the proposed algorithm gives good results based on image quality parameters as compared with the state-of-the-art works in super resolution (SR) process.**

***Keywords*—Super resolution, DWT, SWT, Lanczos interpolation, Canny edge extraction, NLM.**

I. INTRODUCTION

A high-cost sensor can provide an HR image and we can obtain more detailed information from that HR image. But achieving an HR image it consists lots of cost due to the cost of expensive sensors. So one basic solution to this problem is to convert LR images to the HR images with the help of super resolution algorithms. Increasing the resolution of the image with the super resolution algorithm enable us to retrieve more detailed information from the image. Interpolation can increase the number of pixels in the image. Nearest neighbor, Bilinear and Bicubic interpolation can increase the resolution of the image but these techniques provide blur at the edges of the image [1], [2]. Nowadays super resolution work has been moved towards the wavelet transformation techniques [3],[4]. Discrete wavelet transformation is used for Multi-resolution analysis and Demiral et. Al gave an algorithm using DWT [5]. Further,SWT with the DWT to overcome the translation invariance issue of DWT was introduced [6]. Muhammad et.Al used Complex wavelet transform to increase the resolution of the image [7].Ensuring more information at the edges is the most critical task in the SR process. Roman et.Al gave an algorithm in which Sobel operator was used to preserve the edges and he applied NLMfilter to achieve sharper images [8]. Then Herminio et. Al introduces sparse representation with wavelet domain to increase the resolution of the images [9].

In this paper, DWT and SWT both have been used to increase the resolution of LR images and to preserve more edges of the image Canny edge operator has been applied which shows better result than other edge extraction operators [10]. To interpolate the image Lanczos interpolation is used which shows superiority over Bilinear, Bicubic and Nearest neighbor due to its increased ability to detect edges and linear features and it also provides reduced ringing and aliasing effects [11]. To reduce the artifacts generated due to the DWT and to obtain a sharper image by reducing the noise in LR image NLM filter has been used.

To check the effectiveness of proposed algorithm(ISRDS-Canny-NLM) different quality parameter of the image like PSNR, RMSE and SSIM are calculated over the standard input images and this algorithm is giving good results than other state-of-the-art techniques in SR process.

II. PRELIMINARIES

A. NLM FILTERING

To denoise a pixel NLM filtering is used. It is not done in random fashion, every pixel is given a weight which shows the probability of repeating contents of a pixel which is to be denoised. A weighted average of those surrounding pixels is taken to denoise the pixel. A pixel $x(m,n)$ can be estimated as by taking a weighted average of surrounding noisy pixels $y(m,n)$.

$$\hat{x}(m,n) = \frac{\sum (r,s) \in Q(m,n) y[r,s] W[m,n;r,s]}{\sum (r,s) \in Q(m,n) W[m,n;r,s]}$$

Where Q (*m*, *n*) represents neighborhood pixel of y (*r, s*).

$W[m,n;r,s]$ is a weight for (*m,n)*th neighbor pixel and weight can be calculated as:

$W[m,n;r,s] = \exp\left\{-\frac{(y[m,n]-y[r,s])^2}{2\delta^2}\right\}.g\sqrt{(m-r)^2+(n-s)^2}$. The parameter δ controls the effect of the gray level difference between two pixels.

B. Canny Edge Extraction

In Resolution enhancement edge preservation is a very important issue. To preserve the edges within the image Canny edge operator can be used. Canny edge operator works in following way [11].

First it finds the derivate in x and y direction of the image then it sets two threshold value one for the upper bound and another one for the lower bound, then if a pixel value is reached higher than upper bound it is considered as an edge and if it is lower than lower bound it is rejected. Pixel values which are between upper and lower bound only then are considered if they are connected to a pixel which is considered as an edge.

III. PROPOSED METHOD

In this proposed work, Input image for this algorithm is taken by down-sampling the original image with the help of DWT as its LL sub band is retrieved through only low pass filter.So this low pass filtered image having blur is used as the input image. DWT and SWT are applied on input image which gives LL,LH,HL and HH sub bands.Then bands retrieved from DWT are interpolated with Lanczos interpolation with factor 2.High-frequency bands retrieved by SWT is added to sub-bands of DWT to overcome its translation invariance issue.Canny edge extraction operator

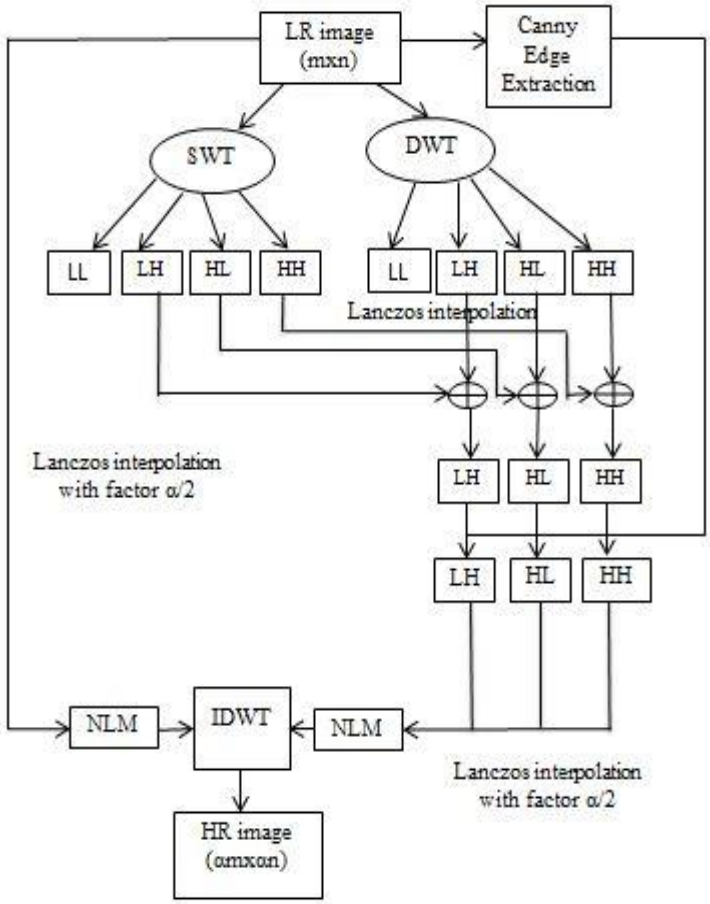


Figure1. Block diagram of the proposed Super Resolution method

detects edges of the input image and this information is added to the estimated sub-bands as shown in figure 1.

Then the input image and sub-bands are interpolated with Lanczos interpolation with factor α/2 and NLM is applied on both direction of this algorithm that is on input image and on sub-bands to remove the noise and artifacts. Finally, IDWT is applied to restore the original image of factor α.

IV. EXPERIMENTAL RESULTS

This proposed super-resolution algorithm is applied to different input sets in which images like Lena,Mandrill,Elaine and Satellite Arial images are also tested [12].Quality parameters like PSNR,RMSE and SSIM are calculated for this algorithm and results are compared with some well-known super-resolution algorithms.128x128

input images are taken and 512x512 size images are retrieved. In figure 2 test on Lena image is shown and it can be easily seen that proposed algorithm is giving good viewing result and parameter results are given in table 1.

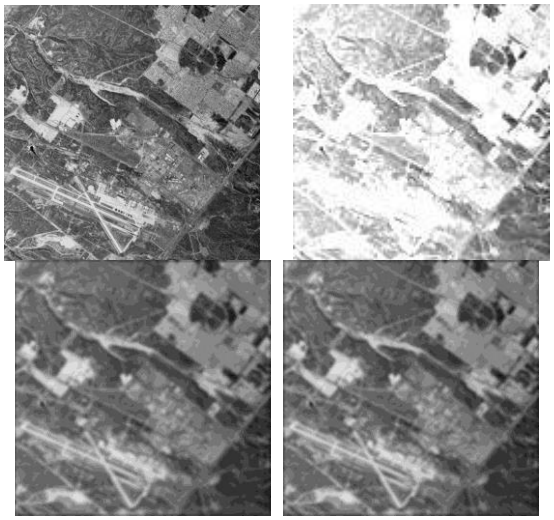
(a) (b) (c)
(d)

(e) (f) (g)

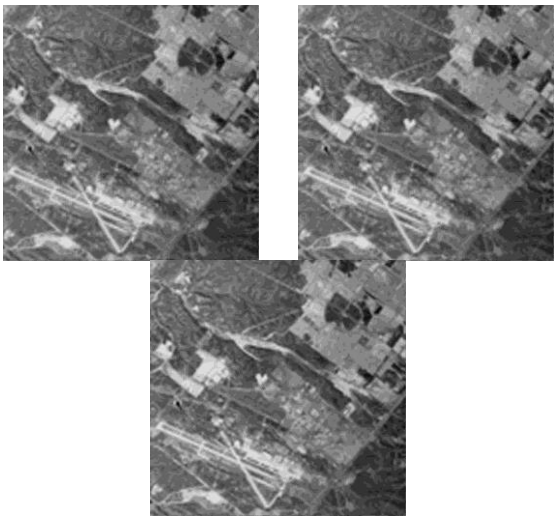
Fig. 2. (a) Original "Lena" image. (b) Input LR image. (c) Bicubic-RE. (d) Lanczos interpolation. (e) DWT-SR.

(f) IREDSWD. (g) Proposed algorithm ISRDS-Canny-NLM.

The Arial image is also taken to check the performance and results from 128x128 resolution to 512x512 resolution is obtained and comparison results are shown in table2.



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



(e) (f) (g)

Fig. 3. (a) Original "Arial" image. (b) Input LR image. (c) Bicubic-RE. (d) Lanczos interpolation. (e) DWT-SR.

(f) IREDSWD. (g) Proposed algorithm ISRDS-Canny-NLM.

Table 1. Quality parameter results for resolution enhancement from 128x128 to 512x512

ALGORITHM	LENA			MANDRILL			ELAINE			BUTTERFLY		
	PSNR	**RMSE**	**SSIM**	**PSNR**	**RMSE**	**SSIM**	**PSNR**	**RMSE**	**SSIM**	**PSNR**	**RMSE**	**SSIM**
BICUBIC-RE	19.0553	56.9715	0.4395	19.0650	56.9077	0.3118	20.7595	48.8213	0.4062	20.2318	49.7541	0.7015
LANCZOS-RE	21.5953	42.5261	0.4465	20.6931	55.4531	0.3221	20.8277	20.7377	0.4065	20.2417	49.3211	0.7081
DWT-SR [6]	31.8625	13.0405	0.4989	22.1748	39.3652	0.2887	32.2161	12.5203	0.4331	27.8173	20.7756	0.5152
IREDSWD [7]	34.9325	9.1579	0.5001	22.2631	39.3792	0.2889	33.1981	10.9654	0.4337	28.0483	20.2305	0.5159
PROPOSED [ISRDS-Canny-NLM]	**35.3856**	**8.6929**	**0.7937**	**30.3880**	**15.4534**	**0.5657**	**34.3634**	**9.7780**	**0.7268**	**30.4494**	**15.3444**	**0.7443**

Table 2. Quality parameter results for Arial image resolution enhancement from 128x128 to 512x512

ALGORITHM	PSNR	RMSE	SSIM
BICUBIC-RE	17.1378	58.4329	0.3926
LANCZOS-RE	18.9496	57.6610	0.4045
DWT-SR [6]	28.6603	18.8542	0.3191
IREDSWD [7]	28.7305	18.7024	0.3559
SR-WDIEE-SR [9]	30.1721	15.8422	0.4092
PROPOSED [ISRDS-Canny-NLM]	**34.0674**	**10.1169**	**0.4907**

After gettin g the results of this method on different images it has been found that this algorithm is giving good results visually as well as after calculating the image quality parameters.

V. CONCLUSION

This paper gives an algorithm for super-resolution which is based on DWT, SWT and Lanczos interpolation to increase the resolution of the image. To extract more edge information Canny edge extraction operator is applied here and NLM filter is used to reduce the noise present in the input image and estimated sub-bands. After calculating parameters it can be seen that this algorithm is showing good performance than other related work in resolution enhancement research area.

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