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An Improved Approach to Super-Resolution Image Reconstruction

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***Abstract*— Super-resolution technique generates an image with high resolution (HR) from image(s) with low resolution. A single image super-resolution technique which reconstructs high resolution images is presented in this paper. This method takes advantage of both frequency and spatial domain techniques. The approach employed iterative back-projection to minimize the error in reconstruction, and Wiener filter to eliminate high frequency noise in the interpolation process. Robert's edge detection algorithm is applied to preserve the boundary information. The performance of the proposed approach was compared with many of the existing state-of-the art algorithms, and found to provide better results.**

Keywords—tomography; reconstruction algorithms; image resolution; image enhancement

I. INTRODUCTION

Resolution enhancement is one of the most popular terms in image processing. It gives more pleasing view to the human eyes. Super resolution technique is for acquiring a high resolution image from observed low resolution (LR) image(s). Each input image differs from other by different parameters like sub-pixel shift, blur, and noise. The redundant information from the LR image is utilized here.

HR images are always desirable in applications such as satellite imaging, sports photographs, medical imaging, archaeology study, microscopy, computer vision, remote sensing, surveillance systems, target detection and recognition. It is also applicable in high resolution videos, compression, astronomy, etc. The need for zooming of images to analyze visual information also increases the demand of super-resolution.

We can improve resolution using complex image acquisition techniques or by increasing the chip size. These remedies are practically difficult because of the high cost. Another solution for resolution improvement is to reduce the pixel size. But, this method is likely to introduce shot noise which diminishes the quality of images. These difficulties made to exploit image processing techniques for resolution enhancement. As the software costs are low when compared to the hardware techniques, super-resolution techniques became popular within a short period.

SR algorithms can be mainly classified into two. One, the frequency domain approach and the other, the spatial domain approach. We can make use of any of these techniques. The benefit of frequency domain approach is its simplicity and low computational overhead; however, it is less flexible. Spatial domain approaches provide high flexibility and more efficient reconstructed images.

II. RELATED WORKS

First contribution to the super-resolution research was by Tsai and Huang [1]. They introduced frequency domain approach for HR image reconstruction using aliasing in the LR images. It focuses on three concepts of Fourier transform: a)Shifting property, b)the continuous Fourier transform (CFT)- Discrete Fourier transform (DFT) relationship and c) the HR image is assumed to be band-limited. The advantages of Tsai-Huang approach is its theoretical simplicity and low computational complexity. It also reduces hardware complexity by enabling parallel implementation.

Projection onto Convex Sets Approach (POCS) was introduced by Stark and Oskoui[2]. It is one of the prominent approaches in Set Theoretic Method. This method can be used as an alternative to least squares or matrix inversion technique. It solves restoration and interpolation problem using registration parameters. In order to include sensor noise, Tekalp et al.[3] extended the POCS formulation. Later, the motion blur occurring during the aperture time of the camera was addressed by Patti et al.[4]. The advantage of POCS is its simplicity and powerful insertion of a-priori information.

Irani and Peleg[5] suggested iterative back-projection (IBP) approach which uses an iterative algorithm for SR reconstruction. The method is adopted from the back-projection approach used in Computer Aided Tomography (CAT). The advantage of IBP is its simplicity. Inclusion of priority constraints is not easily achieved in the IBP method.

A technical survey conducted by Sung Cheol Park et al.[6] explains the SR technology and provides an outline of main SR approaches and related issues. The article begins by illustrating the need of super resolution in this era. Then, it discusses the methods to improve resolution and the research in SR algorithms. An observation model to relate input LR image(s) and output HR image is formulated. The authors also emphasize the role of SR algorithm in compression system.

Evolutionary approaches are also used in super-resolution reconstruction. An important work in this direction is that by Felix Totir et al. [7] who proposed evolutionary computation technique that is useful to solve optimization problems. Genetic algorithms [8] are suitable

for the situations like insufficient information and noise. Since both the pixel values of image and genomes are represented as integers, genetic algorithm gives better performance in comparison with the conventional methods. It simplifies computational complexity by avoiding complex mathematical operations.

Super-resolution technology has significant role in medical imaging. By applying SR technology on medical imaging, true isotropic 3D imaging can be performed. Greenspan [9] gave an excellent review on SR techniques in medical imaging. Kouame and Ploquin [10] emphasized the power of SR technology in their paper. Based on the analysis of the point spread function (PSF), a new technique for achieving super-resolution is employed. Here, estimation of B-mode images is done by using parametric modelling. Sable and Gaikwad [11] designed an SR technique that includes pre-processing and post processing. The authors claim that it can improve the performance of adaptive iterative algorithm.

Example-based super-resolution method presented by SendaShuji et al.[12] belongs to one of the latest SR technique called learning based approach. It enables the reconstruction of magnified SR images like license plates and human faces. The advantage of learning based approach is that it requires very few LR images when compared to the conventional techniques. It is faster, more versatile and provides high magnification factor (MF).

Marco Bevilacqua [13] described an example based single image super-resolution technique. This algorithm uses negative neighbour embedding technique. This approach achieves high performance and low computational overhead; but it is often affected by ringing aircrafts.

Shi Chao et al.[14] employed a novel super-resolution technique using interpolation algorithm. The idea is based on weighted least square method. In this paper, resolution enhancement from a single-frame image is discussed. This method exploits more information for SR reconstruction compared to the conventional method. The visual impression and the objective evaluation index are superior to that of other conventional methods.

Venkatesh and Govindan[15] presented an improved resolution method using geometric image registration. The approach makes use of geometric registration, feature detection and contrast stretching. This algorithm gives better results and achieves good accuracy and reduced processing time. The drawback of this method is that the Hough transform misleads the results when objects happen to be aligned by chance and it requires lots of memory and computation for objects with many parameters.

The rest of this paper is organized as follows. Section III presents the proposed scheme. Comparative study with different existing methods is given in Section IV. Finally, Section V concludes the work with future scope.

III. PROPOSED WORK

The basic idea of the proposed method is adopted from [16]. Wiener filter is introduced to remove the noise in the high frequency sub-band. In addition to that Robert's cross edge detection algorithm is used to preserve image boundaries. Flowchart of the proposed approach is shown in

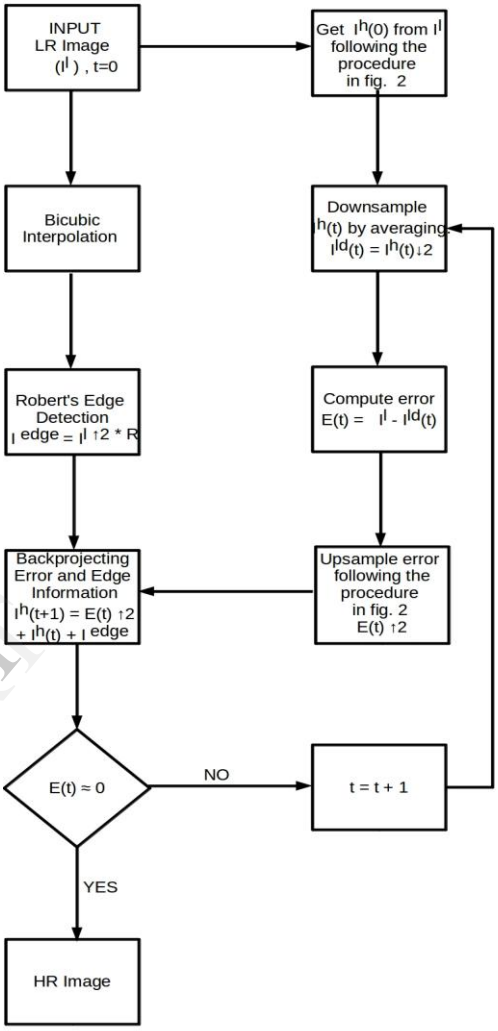

Fig. 1. The algorithm is briefly presented in the following subsection.

Flowchart of the proposed algorithm

A. *Proposed Algorithm*

Input : LR image

Output : HR image

1. Input a LR image, I^l.t=0.

2. Upsample the image as follows (Fig. 2).

i) Construct initial high resolution image by combining the high wavelet subbands (LH,HL,HH) of bicubic interpolation and low wavelet band (LL) of WZP (Wavelet Zero-Padding Interpolation).

ii) Remove the high frequency noise by applying Wiener filter on the HH subband of combined image to get $I^h(t)$.

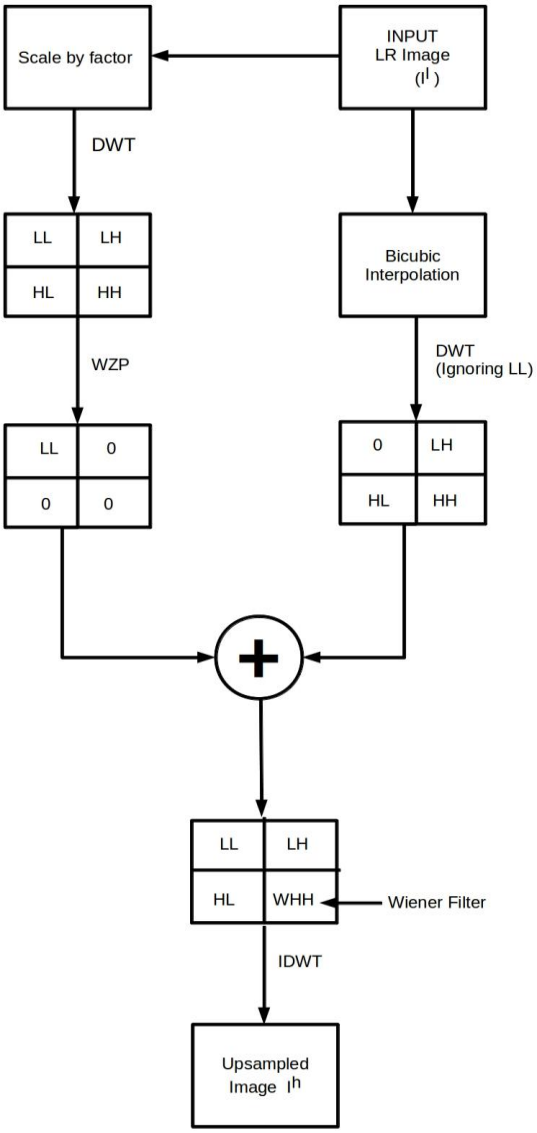

Fig. 1. Algorithm for upsampling

3. Perform Bicubic interpolation on the input image ,I^l. Apply Robert's Edge Detection algorithm on it to preserve the edge information in high frequency subbands(I^{edge}).

$$I^{edge} = I^l\uparrow_2 * R \quad (1)$$

where R is Robert's edge detector.

4. Down sample the image in step 2 by averaging to get $I^{ld}(t)$

5. Reconstruct the error E(t)

$$E(t) = I^l - I^{ld}(t) \quad (2)$$

6. Up sample the error using the method used in step 2.

7. Back-project the error and edge information : High resolution image is updated using *Iterative back-projection*(IBP) method.

$$I^h(t+1) = E(t)\uparrow_2 + I^h(t) + I^{edge} \quad (3)$$

8. Repeat from step 4 until convergence or pre specified criteria is met

IV. Experimental Results and Discussion

The algorithm is implemented in MATLAB. A comparative study based on PSNR and SSIM(Structural Similarity) is performed between the proposed algorithm and some of the existing algorithms. These two parameters (PSNR & SSIM) are computed for bilinear, bicubic[17], wavelet with zero-padding(WZP) interpolation, wavelet and spatial domain(WS)[16] approach and the proposed method. Experiment is conducted on five 512×512 standard test images. Results are given in Fig. 3 and the quantitative evaluations are tabulated as in Tables I and II. The proposed approach provides better performance in terms of PSNR and SSIM for all of the cases of test images. The introduction of denoising in the up-sampling procedure using Wiener filter and the preservation of edges with Robert's edge detector lead to the overall improvements in the quality of reconstruction.

TABLE I. Performance Comparison of the Proposed Approach with Different Approaches Based on PSNR.

	Biliner	**Bicubic[17]**	**WZP**	**WS[16]**	**Proposed Method**
Image 1	31.6220	33.2173	30.2551	32.7244	**34.0103**
Image 2	20.0405	20.5100	19.9942	20.3134	**20.7037**
Image 3	25.0757	25.4942	25.1826	25.0803	**25.6699**
Image 4	26.2025	27.4839	25.3876	27.2803	**28.0926**
Image 5	25.8165	26.9172	25.0925	26.5610	**27.4145**

TABLE II. Performance Comparison of the Proposed Approach with Different Approaches Based on SSIM

	Biliner	**Bicubic[17]**	**WZP**	**WS[16]**	**Proposed Method**
Image 1	0.8888	0.9118	0.8778	0.9229	**0.9294**
Image 2	0.6244	0.6624	0.6422	0.6792	**0.6860**
Image 3	0.7606	0.7937	0.7682	0.8103	**0.8175**
Image 4	0.8259	0.8687	0.8110	0.8715	**0.8887**
Image 5	0.7338	0.7746	0.7320	0.7860	**0.7972**

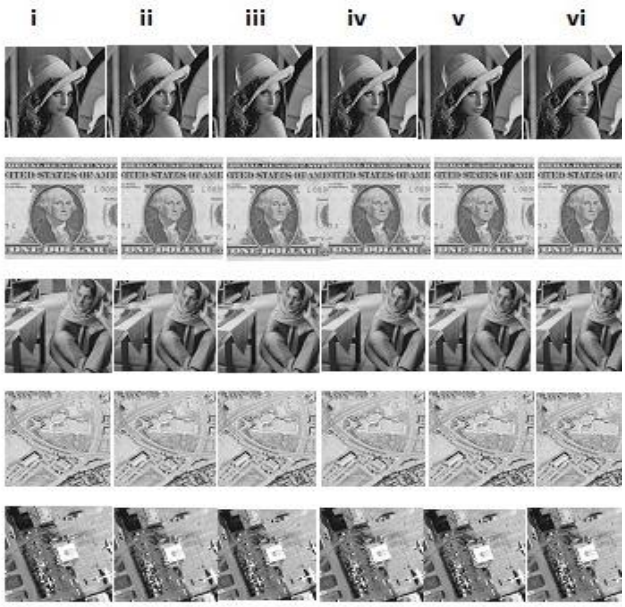

Fig. 2. :Resolution enhancement demonstrated on various test images.(i) Original image, (ii)bilinear, (iii)bicubic, (iv)WZP, (v)WS, (vi)Proposed method

V. CONCLUSION

An improved method for single image super-resolution reconstruction is proposed in this paper. The algorithm exploits the advantages of both frequency and spatial domain techniques. The approach makes use of the Wiener filter for de-noising and the Robert's edge detector for preserving edges in the reconstruction process. Experimental results demonstrate that the method proposed here can produce better quality images when compared to the results of the approaches- Bilinear, Bicubic, WZP and WS given in the literature.

An improved up-sampling, de-noising and edge detection processes can further increase the efficiency of the algorithm.

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