Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IMPACT FACTOR: 5.258

IJCSMC, Vol. 5, Issue. 6, June 2016, pg.495 – 499

A Review on Image Resolution Enhancement Methods in Spatial and Frequency Domain

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Abstract— In computer vision field, Image resolution enhancement has become the most current research area. Improving image resolution by applying costly hardware is expensive and time-consuming. In this paper we have discussed different methods to improve the resolution of the single image and we have given a comparison of different Super resolution algorithms for standard images based on PSNR and SSIM (Structure Similarity Index).

Keywords— Resolution Enhancement, Super-resolution, Spatial domain, frequency domain, PSNR, SSIM

I. INTRODUCTION

Zooming a picture is ver essential in the field where someone wants to obtain more detailed information from an image. Low resolution(LR) images do not contain more information so to retrieve more information from that image Super-resolution(SR) is applied on LR images. The resolution enhancement work began in 1984 when Tsai and Huang [1] has introduced a mathematical model to obtain a single high-resolution image from a single or multiple LR images. This paper provides the review of the work done in the area of super-resolution in the spatial as well as in the frequency domain. This paper is organized into following sections. Section II describes spatial domain methods of super-resolution, section III gives method in the frequency domain, section IV contains comparison between some of the well-known algorithms and finally in the last section Conclusion is drawn.

II. SUPER RESOLUTION METHODS IN SPATIAL DOMAIN

1. Nearest-Neighbor Interpolation

When an image is interpolated new holes or pixels get generated and they need some value so that they can contain some information. In nearest-neighbor interpolation new interpolated pixel gets the pixel value of its neighbouring pixel.[2]

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2. **Bilinear Interpolation**
In Bilinear interpolation new interpolated pixel gets the value which is obtained by taking a weighted average of its neighbouring 4 pixels. For new pixel gray level will be:

$$f(x,y) = \frac{1}{(x_2 - x_1)(y_2 - y_1)}[f(q_{11}(x_2 - x)(y_2 - y)) + f(q_{12}(x_2 - x)(y - y_1)) + f(q_{21}(x - x_1)(y_2 - y)) + f(q_{22}(x - x_1)(y - y_1))]$$

Where $f(q_{11})$, f(q21) , $f(q_{12})$, $f(q_{22})$ are the gray level of the pixel q_{11} , q_{21} , q_{12} , q_{22}.

3. **Bicubic Interpolation**
It works as a cube and new interpolated pixel gets the value of the weighted average of nearest 16 pixels. It gives a better result than Nearest-neighbor and Bilinear interpolation. New pixel will have gray level:

$$g(x,y) = \frac{1}{16}\sum_{l=-1}^{2}\sum_{m=-1}^{2} f(x+l, y+m)u(dx)u(dy)$$

Where f(x+l,y+m) = Gray value of that pixel, u(dx)= variation on x-axis, u(dy)=variation on y-axix.

4. **Lanczos Interpolation**
Lanczos window sinc kernel is used [3] to compute the value of interpolated pixels. Lanczos interpolation works on 4x4, 6x6 and 8x8 cell of pixels. 4x4 is same as Bicubic with no sharpening. This method gives good result than Bicubic but takes longer time to compute.
Interpolation formula for Lanczos is-

$$S(x) = \sum_{i=\lfloor x \rfloor - a + 1}^{\lfloor x \rfloor + a} s_i - L(x-i)$$

It is 1-D formula for interpolation, where a is the filter size parameter and $\lfloor x \rfloor$ is the floor function. $L(x-i)$ is the kernel of lanczos interpolation.

$$L(x) = \begin{cases} \sin c(x) \sin c(x/a) & \text{If } -a<x<a \\ 0 & \text{Otherwise} \end{cases}$$

5. **NEDI(New Edge-Directed Interpolation)**
In NEDI we first estimate local covariance coefficients from a low-resolution image and then these covariance are estimated to interpolate at a higher resolution based on the geometric duality between the low-resolution and high-resolution covariance.[4]

III.FREQUENCY DOMAIN METHODS OF RESOLUTION ENHANCEMENT

Spatial resolution image can be converted to the signal representation by applying transformation techniques on the image.

1. First work in the frequency domain was done by Tsai and Huang [1] and many researchers have subsequently expanded this approach to increase the resolution of the image. The work of Tsai and Huang [1] was based on continuous Fourier transform(CFT) and in this work blur and noise during image acquisition were ignored.

2. Lately the Fourier transform work was replaced by DCT(discrete cosine transform) and DWT(discrete wavelet transform). Rhee and kang [5] replaces the Fourier based technique and gave a DCT based method which works on real coefficients. Therefore it is less expensive in terms of computation than Fourier.

3. Recently researchers moved there idea towards the DWT [6-12]. Nguyen and Milanfar [6] used wavelet interpolation and after that restoration was performed to increase resolution. Demiral et Al. gave an

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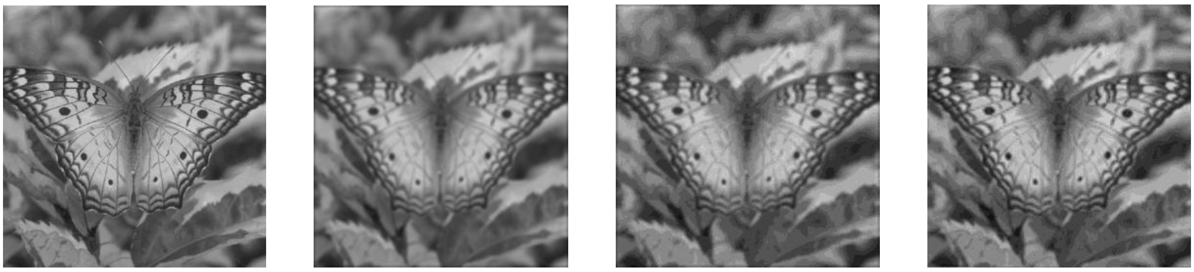
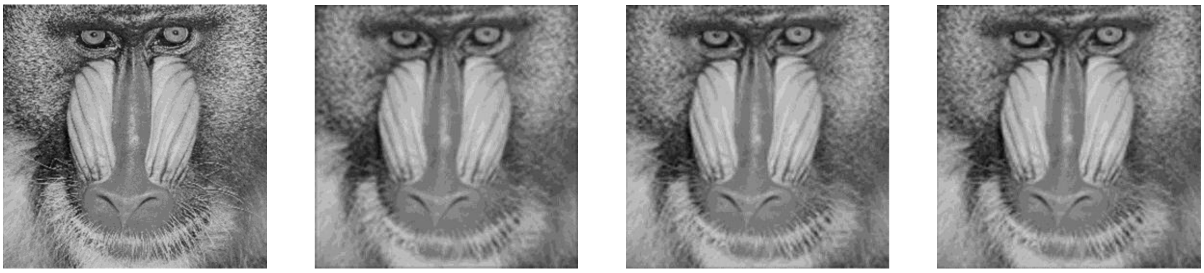
algorithm in which they used DWT to perform SR [13]. After that Demial et Al. also introduced SWT(stationary wavelet transform) with DWT to overcome the translation invariance of DWT[14]. H. Demiral moved from DWT to DT-CWT(dual tree-complex wavelet transform) and used NEDI interpolation [15]. Muhammad Zafar el Al. uses NLM (Non Local Mean) filter with DT-CWT to address SR problem [16] and then Herminio et Al. uses sparse representation with DWT [17]. Rakesh and Manjunath used optimal wavelet filter coefficients and sparsity regularization to perform super-resolution on Hyperspectral images [20].

IV. EXPERIMENTAL RESULTS

For frequency and spatial domain resolution enhancement different-different algorithms were proposed. To check the effectiveness, different standard images are taken of 128x128 and 512x512 sizes image is retrieved. Results of these methods are shown in table 1. Image quality metric results will verify that which domain methods give better results and for this purpose PSNR and SSIM choosen as a quality metric.



a)Original Butterfly image(512x512) b) Bicubic(512x512) c) NEDI(512x512) d) DWT(512x512)



e) Mandrill original (512x512) image f) Lanczos (512x512) g) SDWT(512x512) h) SR-WDIEE(512x512)

Figure 1. Result of Some algorithms on Btterfly and Mandrill images

Table-1: Quality Metric for different Algorithms tested upon 128x128 to 512x512

SR Methods	BUTTERFLY		LENA		MANDRILL	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Bicubic Intp.	22.13	0.854	26.17	0.840	20.61	0.747
NEDI	26.46	0.848	26.44	0.835	21.18	0.754
Lanczos intp.	25.14	0.895	27.12	0.910	22.13	0.767
DWT-SR	32.12	0.920	34.36	0.945	23.29	0.812

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Sparse representation (Zeyde et al.)	27.6	0.952	31.2	0.986	22.46	0.790
SDWT-SR	28.76	0.960	34.82	0.988	23.87	0.840
SR-WDIEE-SR	29.54	0.978	34.98	0.990	24.01	0.862

V. Conclusion

Image resolution enhancement can be increases via both spatial and frequency domain methods but in spatial domain there is big loss of edge information of image that is why researchers now moved there interest towards the frequency domain. Image quality parameters are showing that the algorithms which are defined in the frequency domain are giving better results over spatial domain methods. DWT is current research area in the resolution enhancement of the LR images and the algorithms which are using DWT show better results than other methodologies.

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