iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** IX **Month of publication:** September 2016

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Image Super Resolution Using Wavelet Analysis

Radhika S. Karpe[1], Prof. D. D. Ahire[2]
[1] *Student* , [2]*Professor, Department of E&TC, Matoshri College of Engineering and Research Centre, Nashik,*
[1, 2] *Savitribai Phule Pune University, Pune, Maharashtra, India*

Abstract—The aim of image resolution enhancement is to process a given input low resolution image to make the result more desirable than the original image for a given specific application. In the work, we have proposed an image resolution enhancement technique that generates sharper and high resolution output image. The proposed technique utilizes DWT for decomposing low resolution image in separate sub-bands. Then the above three higher frequency band images are interpolated by the utilization of bi-cubic interpolation. This higher frequency bands generated by stationary wavelet transform of the given input image are then increased into the interpolated higher frequency bands in order to correct the coefficients. The given input image is interpolated in parallel. At last, correctly estimated interpolated higher frequency bands and interpolated input image are mixed by utilizing inverse DWT (IDWT) for getting enhanced output image. After that there is a comparison between the conventional techniques for image enhancement and state-of-the-art image enhancement techniques. One level DWT having Daubechies 9/7 as the wavelet function is utilized to decompose given input image into separate band images. The three higher frequency bands (L-H, H-L, and H-H) has the higher frequency contents of the given input image. In this pro-posed method, bi-cubic interpolation which has increment factor as '2' is then given to higher frequency band images. Due to application of down-sampling in each of the DWT bands there is loss of information in the respective given sub-bands. Hence, SWT is utilized to reduce the losses.
Keywords— Discrete wavelet transform, image super resolution, stationary wavelet transform.

I. INTRODUCTION

Out of all five senses vision is most advanced, so it is not surprised that images play the single most important role in human perception. Human vision is limited to visual band of electromagnetic (EM) spectrum, while imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves. They can work on images created by source that humans are not customary to associate with images. These include electron microscopy, computerize images. Digital image processing works same way as the human vision system. It involves the process of acquiring, analyzing and manipulating images using digital computers. There are various physical devices to capture digital images like camera, satellite, magnetic resonance imaging machine and microscope etc. The area of application of digital image processing is very vast. With increase in demand and performance of personal computing digital image processing is widely being used in many applications. Digital image process has advantage in term of cost, speed and flexibility. The objective is to bring out information from the scene being viewed. Digital image processing can be classified in following subareas on the basis of nature of application.
Image Enhancement
Image Restoration
Image Compression
Image Segmentation
Image Understanding
A digital can be represented by function of two dimensional variables and mathematically can be represented as

$$I = f(x, y) \qquad (1)$$

here I is an image, x and y are spatial coordinates, and f is the amplitude of any pair of coordinates (x, y) and is called as intensity or grey level of the image at that point. When values of coordinates (x,y) and amplitude f all are finite and discrete quantities, the image is called digital image. A digital image is composed of finite number of elements, all of which has particular location and value. [1]These elements are called picture elements, image elements, pels and pixels.
There are various image processing application requires high resolution images for processing and analysis. The desire for high resolution images came from two principal application areas: improvement of pictorial information for human elucidation; and helping representation for automatic machine perception. Image resolution describes the amount of information contained by images. Lower resolution less would be the amount of information, higher resolution more would be amount of considered. Interpolation filters are designed by analyzing correlation between sub-bands having different sampling stages in the lower level, and applied to

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the correlated sub-bands information in images. Resolution of a digital image can be classified in many ways: pixel resolution, spatial resolution, spectral resolution, temporal resolution, and radiometric resolution.[1] A digital image is made from small picture elements called pixels. Spatial resolution mentions the pixel density in an image and measures in pixels per unit area.

Resolution has been often referred as an important aspect of an image. Images are being processed in order to obtain more improved resolution. One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been used in various image processing applications such as facial reconstruction, multiple description coding, and super resolution. There are three well known interpolation techniques, namely nearest neighbor interpolation, bilinear interpolation, and bi-cubic interpolation. Image resolution enhancement in the wavelet domain is a relatively new research topic and recently many new algorithms are proposed. [9] Discrete wavelet transform (DWT) is one of the recent wavelet transforms used in image processing. DWT 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 various image processing applications is stationary wavelet transform (SWT). In short, SWT is similar to DWT but it does not use down-sampling, therefore the sub-band have the same size as the input image.

In the work, an image resolution enhancement technique is being proposed which generates sharp high resolution image. The proposed technique utilizes DWT to decompose a low resolution image into different sub-bands. Then the three high frequency sub-band images are then interpolated using bi-cubic interpolation. The high frequency sub-bands which are obtained by SWT of the input image are being incremented into the interpolated high frequency sub-bands in order to correct the calculated coefficients. In parallel, the input image is interpolated separately.

Finally, improved interpolated high frequency sub-bands and interpolated input image are combined using inverse DWT (IDWT) to get a high resolution output image. [9] The proposed technique has been compared with conventional and the state-of-art image resolution enhancement techniques. The conventional techniques used are the following.

Bilinear interpolation

Bi-cubic interpolation.

Wavelet zero padding (WZP).

According to the quantitative and qualitative experimental results, the proposed technique well over performs the abovementioned conventional and state-of-art techniques for image resolution enhancement.

II. LITERATURE SURVEY

In order to start the thesis, the first step is to study the previous work performed by researchers. For this purpose various papers have been studied. Below are the literature review in image enhancement by some authors and their main observations:

A. Regularity-preserving image interpolation

Author estimated the regularity of edges by measuring the decay of wavelet transform coefficients across scales and restores the underlying regularity by extrapolating a new sub-band to be used in image re-synthesis. The algorithm produces visibly sharp edges than traditional techniques and gives an average peak signal-to-noise ratio (PSNR) improvement of 2.5 dB over bilinear and bi-cubic techniques. By W.K. Carley, D.B. Chuang and S.S.Hemami.

B. Optimal image scaling using pixel classification

Author introduced a new approach to optimal image scaling called resolution synthesis (RS). In RS, the pixel interpolated is first classified in the context of a window of neighboring pixels; and the corresponding high resolution pixels are obtained by filtering with coefficients that depend upon the classification. By C.B. Atkins, C.A. Bouman and J.P. Allebach.

Shape-adaptive coding using binary set splitting with k-d trees: An embedded wavelet image coder based on the popular bitplane-coding paradigm, BISK is designed specifically for the coding of image objects with arbitrary shapes. Empirical results indicate that the proposed BISK coder consistently gives efficient performance when compared to a variety of other shape-adaptive coders. By J.E. Fowler.

Image resolution enhancement utilizing inter-sub-band correlation in wavelet domain: In this paper, author proposed a new resolution enhancement method utilizing inter-sub-band correlation in which the sampling phase in DWT in the higher level. By Y. Piao, I.Shin and H.W. Park.

The wrinkle generation method for facial reconstruction based on extraction of partition wrinkle line characterizes and patterns interpolation: Because of the high putrescibility of the body, in general condition only part of bones can be found when the victim body was discovered. Therefore, in the first step of the criminal investigation is to reconstruct the facial characteristics in order to find the victim. Because wrinkle is the most remarkable and intuitionistic characteristics in the human skin, the wrinkle generation method for reconstructed face is an important step of facial reconstruction. By L.Yi-bo, X.Hong and Z.Senyue.

Downsample-based multiple description coding and post-processing of decoding: This work proposed an image resolution enhancement technique which is build on the interpolation of high frequency sub-bands obtained by DWT. The proposed technique uses DWT to decompose an image into different sub-bands, and then the high frequency sub-band images are interpolated. By H. Demirel and G.Anbarjafari.

Image resolution enhancement by utilizing discrete and stationary wavelet decomposition: In this correspondence the authors proposes an image resolution enhancement technique build on interpolation of the high frequency sub-band images obtained by DWT and the input image. The edges are then enhanced by introducing an intermediate stage by utilizing SWT. DWT is applied to decompose an input image into different sub-bands. Then the high frequency sub-bands as well as the input image are interpolated. By A.Bouman.

III. PROPOSED SYSTEM

In image resolution improvement by the process of interpolation the main higher frequency components are at the highest loss (i.e., edges), which is because of the cause smoothing in the interpolation procedure. In this process to improve the features of the enhanced image, to preserve the edge contents is a must do process. In the work, DWT is utilized in preserving the higher frequency components in the image. The redundancy feature and the invariance in shift of DWT says that DWT coefficients are always inherently interpolable.

In this project, level one DWT with the wavelet function Daubechies sub-family 9/7 is utilized for the decomposition of an input image in various sub-band images. Three higher frequency band contents (L-H, H-L, and H-H) containing the higher frequency contents of the given input image. In our proposed technique, we are utilizing the bi-cubic interpolation which has ‘2’ as factor of enlargement and is given to higher frequency band image components. Down-sampling in each one of the DWT band image components causes the loss of information in the given respective sub-bands. This is reason we are employing SWT to reduce the loss [1].

There is same or equal size of interpolated higher frequency bands and the SWT higher frequency bands which says there is addition between the two. The newly correct higher frequency bands are then interpolated again for high level of enhancement. In the domain of wavelet it is known that, the images of lower resolution are generated by low-pass filtering process of the higher resolution image. Lower frequency band is the low resolution component of the input original image. Hence, in case of utilizing low frequency sub-band image, having information which is less in amount than the real higher frequency band image, we then utilizing image of input in the process of interpolation of lower frequency band images. [1] Utilizing image of input signal in case of lower frequency band image improves the features of the enhanced image. Fig 1shows the block diagram of the proposed technique for image enhancement.

Now interpolating the given image by $\alpha/2$, and higher frequency band images by the value of 2 and α which are constants in the intermediate and final interpolation stages respectively, and by application of IDWT, as presented in Fig. 1, the image of output signal contains sharp edges compared to the interpolated image obtained by interpolation process of image of input side directly. This is because of the fact that, interpolation procedure of isolated and separate higher frequency contents in higher frequency bands and utilizing the corrections generated by the process of addition of higher frequency band components of SWT of the given input image, which will restore more higher frequency components after the process of interpolation rather than interpolation of input image directly.

For the reason of measuring the performance characteristics of the techniques some parameters are used. For quantitative performance comparison of the peak signal to noise ratio (PSNR in dB) is frequently used which is defined

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

where MSE is defined as

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left(f(x,y) - \hat{f}(x,y)\right)$$

Volume 4 Issue IX, September 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

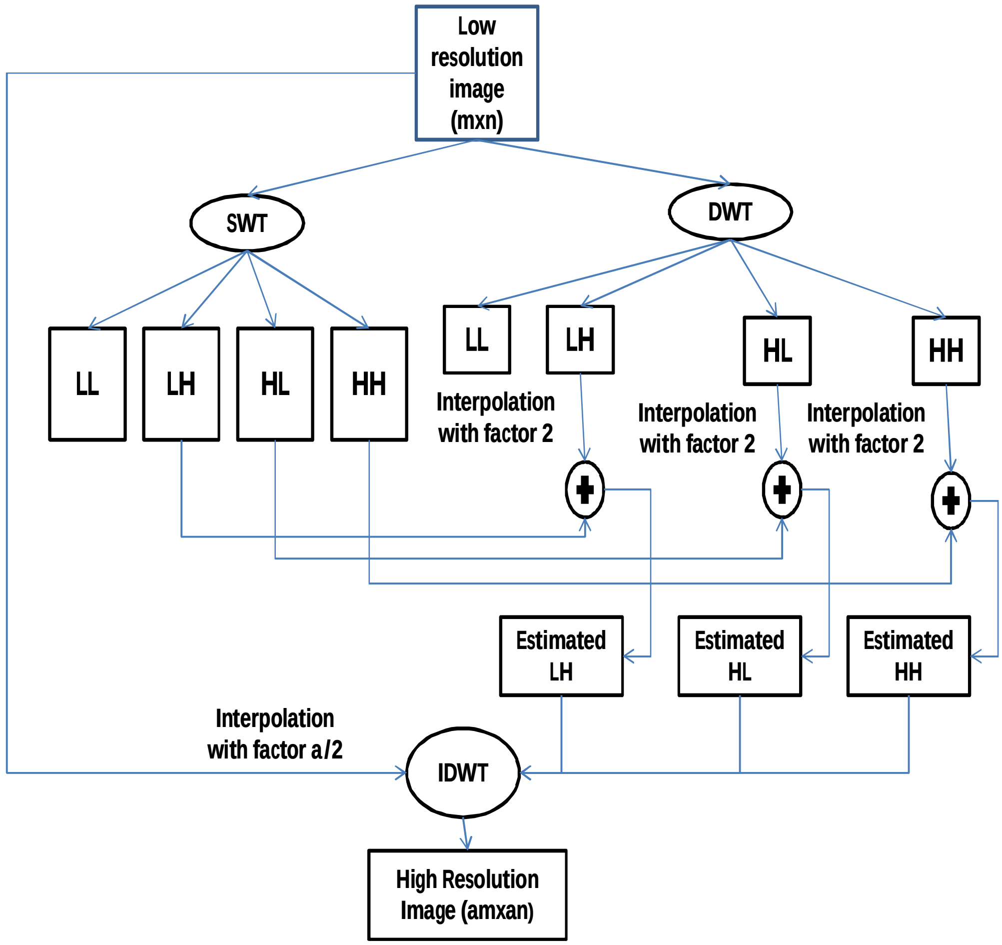


Fig-1: Block Diagram of Proposed System

IV. IMPLEMENTATION AND RESULTS

A. Peak Signal to Noise ratio

The PSNR calculates in two images the peak signal-to-noise ratio, in decibels. This ratio is mostly utilized for measuring the quality between the compressed image and the original image. With increase in the value of PSNR, compressed image, or reconstructed image quality is improved.

To compute the PSNR, the mean-squared error is calculated first utilizing the equation given below:

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left(f(x,y) - \hat{f(x,y)}\right)$$

In the given equation, M is the number of rows and N is the number of columns of the given input image. The PSNR equation is as shown below:

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

B. Mean

The Mean calculates the mean of the input signal of the column or row, along the vectors of a given parameters of the input signal, or may be of the complete input.

Entire input — The output at each and every sample time is a scalar that has the mean value of the M-by-N-by-P input

Volume 4 Issue IX, September 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

matrix.

y = mean(u(:)) MATLAB code

C. Variance

The Variance calculates the variance of every column or row of the input, along the vectors of a given parameters of the input signal, or of the complete input. The function for Variance may track in a period of time the series input variance. There is a selection between running operation and basic operation in parameter of variance.

Complete input — The output at every sample time is a scalar quantity that contains the variance of the entire input.

y = var(u(:)) MATLAB code

D. Standard Deviation

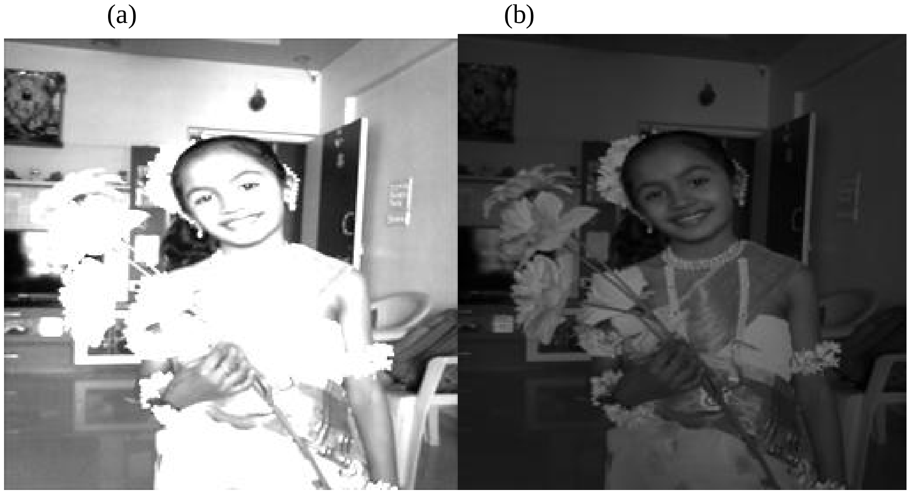
The Standard Deviation calculates the standard deviation of the input signal of rows and column, along vectors of a given parameters of the input, or of the complete input. The Standard Deviation gives the standard deviation of a series of inputs over a period of time. There is a selection between running operation and basic operation in parameters of standard deviation.

y = std(u(:)) MATLAB code

Fig. 2 shows the enhanced image of Sara picture using proposed technique in (f) are good compared with the low resolution image in (a), enhanced image by utilizing the interpolation (b) (c), and WZP (d). The low resolution input image is generated by the procedure of down sampling the high resolution image. In order to show that the proposed method is more effective than the conventional image enhancement methods various features are used for comparison.

Table I compares the PSNR, mean, variance and standard deviation parameters of the proposed technique using bilinear interpolation with conventional resolution enhancement techniques for images: bilinear, bi-cubic, WZP. The results in Table I indicate that the proposed technique over performs the aforementioned conventional image resolution enhancement techniques. Table 1 also indicates that the proposed technique performances are much better than the conventional enhancement techniques for image resolution.

(a) (b)



(c) (d)

Volume 4 Issue IX, September 2016
ISSN: 2321-9653

(e) (f)

Fig 11. (a) Original image (b) Bi-cubic Interpolated image (c) Bilinear Interpolated image (d) Wavelet zero padding image (e) Proposed technique image (f) Proposed plus histogram equalized image.

	PSNR	MEAN	VARIANCE	STD DEVIATION
Bilinear	28.07	1.03	0.211	0.459
Bi-cubic	30.11	0.004	0.03	0.053
WZP	35.93	0.23	0.0105	0.102
HMM SR	35.82	0.968	0.292	0.5404
CWT SR	27.14	0.968	0.294	0.542
NEDI	35.11	0.379	0.043	0.208
Proposed	35.93	0.23	0.0104	0.102
Proposed & Histogram equalization	43.69	0.49	1.0863	0.293

TABLE 1 Results for resolution enhancement of the technique which is proposed compared with the conventional enhancement techniques for image resolution.

V. CONCLUSION

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency sub-bands obtained by DWT, correcting the high frequency sub-band estimation by using SWT high frequency sub-bands, and the input image. 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. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency sub-bands. After-wards all these images have been combined using IDWT to generate a super resolved imaged. The proposed technique has been tested on well-known benchmark images, where their PSNR and visual results show the superiority of proposed technique over the conventional and state-of-art image resolution enhancement techniques.

VI. ACKNOWLEDGMENT

I wish to express my sincere thanks and deep sense of gratitude to respected guide Prof. D. D. Ahire in Department of Electronics and Telecommunication Engineering of Matoshri College of Engineering and Research Centre, Nashik for the technical advice,

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

encouragement and constructive criticism which motivated to strive harder for excellence. I also wish acknowledgement to the people who gives support direct or indirectly to the paper writing.

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