Image Resolution Enhancement Using Undecimated Double Density Wavelet Transform

Varun P. Gopi *varunpg@gecwyd.ac.in*
Department of ECE
Government Engineering College Wayanad
Mananthavady, 670644, Kerala, India

V. Suresh Babu *vsbsreeragam@gmail.com*
Department of ECE
College of Engineering Trivandrum
Thiruvananthapuram, 690015, Kerala, India

Dilna C. *dilnaeramam@gmail.com*
Department of ECE
Government Engineering College Wayanad
Mananthavady, 670644, Kerala, India

Abstract

In this paper, an undecimated double density wavelet based image resolution enhancement technique is proposed. The critically sampled discrete wavelet transform (DWT) suffers from the drawbacks of being shift-variant and lacking the capacity to process directional information in images. The double density wavelet transform (DDWT) is an approximately shift-invariant transform capturing directional information. The undecimated double density wavelet transform (UDDWT) is an improvement of the DDWT, making it exactly shift-invariant. The method uses a forward and inverse UDDWT to construct a high resolution (HR) image from the given low resolution (LR) image. The results are compared with state-of-the-art resolution enhancement methods.

Keywords: Undecimated Double Density Wavelet Transform, Image Resolution, Stationary Wavelet, Resolution Enhancement.

1. INTRODUCTION

Image resolution enhancement is a usable pre-process for many satellite image processing applications, such as bridge recognition, building recognition and vehicle recognition. Image resolution enhancement techniques can be categorized into two major types according to the domain that they are applied in: 1) image domain and 2) transform domain. The techniques in the image domain use the statistical and geometric data directly extracted from the input image itself [1], [2], while transform-domain techniques use transformations such as decimated discrete wavelet transform (DWT) to achieve the image resolution enhancement [3]-[6]. The decimated DWT has been widely used for performing image resolution enhancement [3]-[5]. A common assumption of DWT-based image resolution enhancement is that the low-resolution (LR) image is the low pass filtered subband of the wavelet-transformed high-resolution (HR) image.

The image resolution is always a key feature for all kinds of images. With ever increasing size of the displays need for super resolution images has also been increased. This is also impacted by the limited size of the digital image sensor. Though widespread commercial cameras provide very high resolution images, generally the scientific cameras still have the resolution of only 512 x 512. Resolution enhancement has always been associated with the interpolation techniques.

Research suggests that interpolation methods increase the intensity of low frequency components. This means the interpolated image will have less number of sharp intensity transactions per pixel. A new method for resolution enhancement, which preserves high frequency contents of the image is suggested in the paper. Spatial domain techniques lag in the extraction and preservation of high frequency components of an image. This suggests that some other technique not involving spatial domain is to be used. So the image needs to be transformed to some other domain, processed and then converted back to the spatial domain. The domain can be Fourier domain, wavelet domain or any other. Fourier domain is more suitable for spectral filtering. The spectral filtering removes particular frequencies from the image. Wavelet domain separates components of an image into individual matrices. These matrices can be processed separately and combined together to get the desired result.

Fast algorithms for implementation of discrete wavelet transform have enhanced the use of the wavelet domain for image resolution improvement. Different image processing algorithms can be implemented with discrete wavelet transform (DWT). Double density wavelet transform (DDWT) decomposes an image into nine sub bands. These sub bands are of half the dimensions of that of image under consideration. Undecimated double density wavelet transform (UDDWT) is also being used for the image resolution enhancement. UDDWT has nine sub bands similar to DDWT but sub bands in UDDWT are of same size of that of the image. This paper proposes a new method for image resolution enhancement based on UDDWT.

In this paper, we compared the proposed method with various conventional methods for image resolution enhancement such as NEDI [1], HMM [7], DWT SR [8], DWT&SWT SR [9], LWT&SWT [10]. This comparison of various measures on images shows the dominance of the proposed method over existing methods.

2. DEVELOPMENT OF UNDECIMATED DOUBLE DENSITY WAVELET TRANSFORM

Although the DWT [11, 12, 13] is a powerful signal processing tool, it has two severe disadvantages:

1. Lack of shift-invariance, which means that minor shifts in the input signal, can cause major variations in the distribution of energy between wavelet coefficients at different scales

2. Since the wavelet filters are separable and real, it causes poor directional selectivity for diagonal features

The DWT is shift-variant because, the transform coefficients behave un-predictably under shifts of input signal, a problem that has been treated by introducing large amounts of redundancy into the transform to make it shift-invariant. The DWT has poor directional selectivity because it can only differentiate three different spatial-feature orientations. The DDWT is almost shift-invariant, multi-scale transform and has eight different spatial-feature orientations. Because the DDWT, at each scale, has twice as many wavelets as the DWT, it achieves lower shift sensitivity than the DWT. The undecimated Double Density Wavelet Transform follows the same filter bank structures of DDWT except the up sampling/down sampling process. Here at any given level in the iterated filter bank, this separable extension produces nine sub-bands in the same size as the original image. To indicate the filters used along the row and column dimensions to create the nine sub bands, the label of each of the sub-band is termed as $h_y^i, h_x^j,\ i,j \in \{0,1,2\}$. The subscript x indicates filtering along the rows, while subscript y denotes filtering along the columns. The superscripts 0, 1, 2 indicate the particular filter $\mathrm{h}_0(n)$, $\mathrm{h}_1(n)$, $\mathrm{h}_2(n)$ used to filter along a specified dimension to create the sub bands. Thus, at the end of the analysis filter bank, nine sub-bands will be obtained as shown in Fig. 1. In the UDDWT synthesis filter bank, the decomposed images are filtered using the filter coefficients $g_0(\mathrm{n})$, $g_1(\mathrm{n})$, $g_2(\mathrm{n})$. Fig. 2 illustrates the synthesis filter bank structure, which composes the nine sub bands into a single image. In this work, the image decomposition and reconstruction is done by using the filters designed by Selesnick [14].

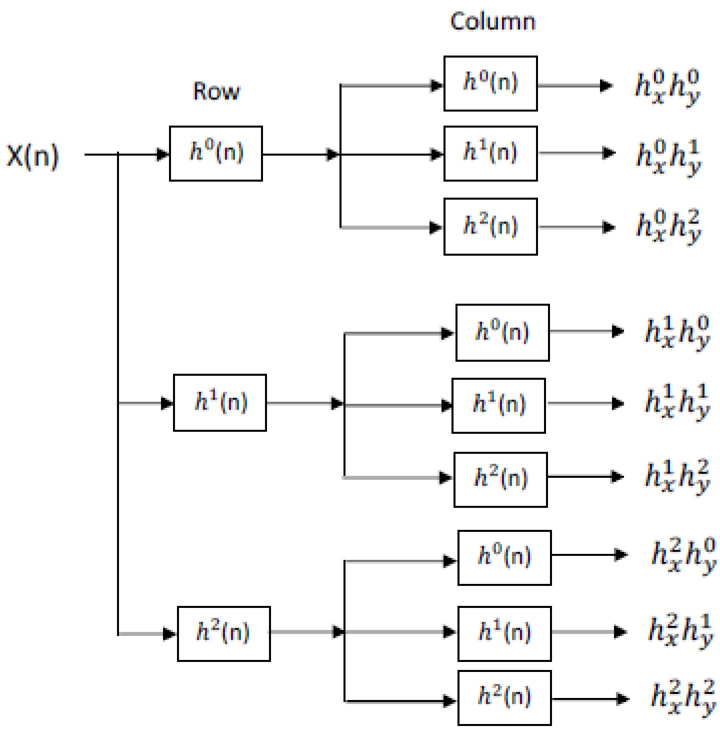


FIGURE 1: UDDWT analysis filter bank structure.

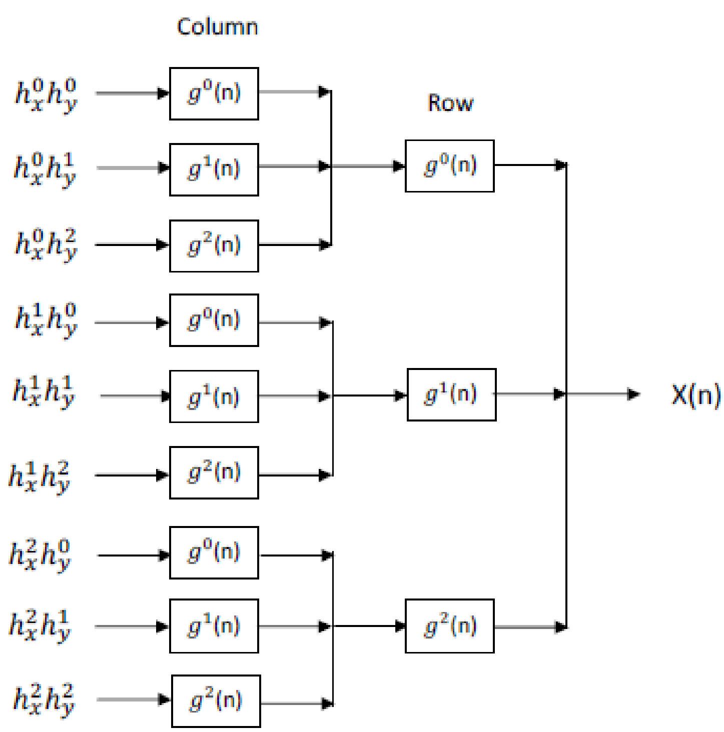


FIGURE 2: UDDWT synthesis filter bank structure.

3. PROPOSED METHOD

In the proposed method low resolution (LR) image is converted into a high resolution (HR) image by using UDDWT. First, apply DDWT and undecimated double density wavelet transform (UDDWT) on the input LR image. The DDWT produces 8 sub-bands which are decimated by factor 2 and an LPF component. Then all 8 subbands are interpolated by factor of β. Similarly UDDWT produces 8 sub-bands and an LPF component. Add corresponding subbands from each of DDWT and UDDWT as shown in Fig. 3. It is known that in the wavelet domain, lowpass filtering of the high resolution image produce the low resolution image. In other words, low frequency subband is the low resolution of the original image. Therefore, instead of using low frequency subband, which contains less information, the original image is used as the input to the inverse UDDWT. The quality of the super resolved image increases when using the input image instead of low frequency subband. Thus the output will be of higher resolution.

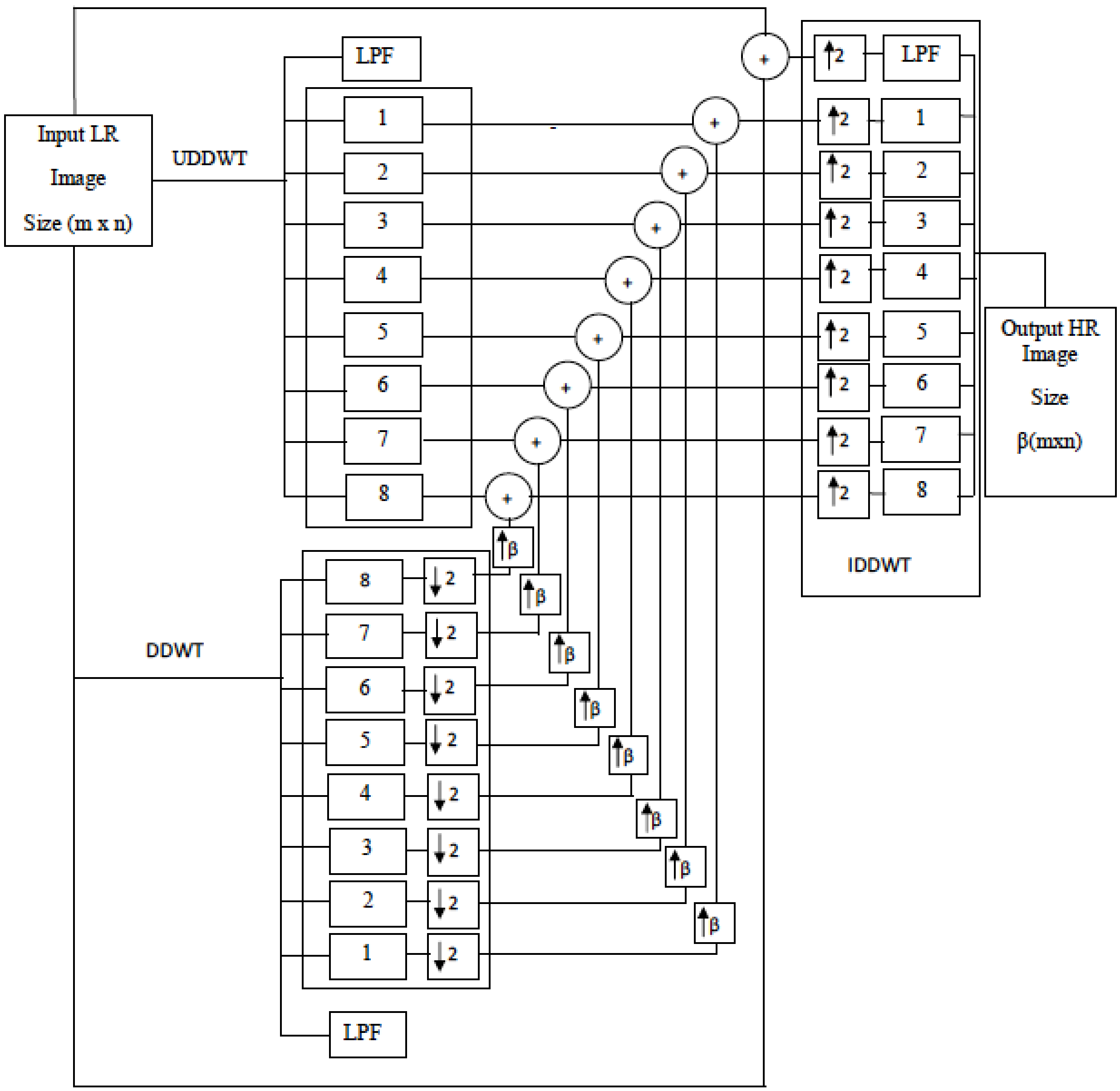


FIGURE 3: Proposed Method.

4. IMAGE QUALITY ANALYSIS

In this proposed work, the performance of the enhanced image is quantitatively analyzed by means of three measures such as peak signal to noise ratio (PSNR), Blind Image Quality Index (BIQI), and Visual Image Fidelity (VIF).

4.1. Peak Signal to Noise ratio (PSNR)

PSNR of the images is computed as

$$\text{PSNR}=10\ log_{10}\left(\frac{I^2_{(m,n)peak}}{MSE}\right)$$

Where $I\,(m,n)peak$ is the peak pixel value in the image $I(m,n)$ and usually is 255.

4.2. Blind Image Quality Index (BIQI)

BIQI [15] is also referred to as no reference image quality index. It refers to evaluating the quality of an image without the need of reference image or any training images. Images with no blur and noise offers higher BIQI value. Different parameters can be used to evaluate the quality of an image blindly**.**

4.3. Visual Image Fidelity (VIF)

VIF index [16] is the ratio of distorted image information to reference image information which is given by

$$VIF=\frac{I(Test)}{I(Reference)}$$

Where $I(Test)$ is the quantity of information extracted from the test image and $I(Reference)$ is the quantity of information extracted from a reference image. The higher the VIF index, higher the magnitude of test image. If VIF reaches to unity means that test image is perfect.

5. RESULTS AND ANALYSIS

The enhancing performance is tested using the images Lena, Elaine, Baboon, and Peppers and all simulations were carried out in MATLAB. Fig. 4 and Fig. 5 illustrates the low resolution test images and enhanced high resolution images respectively. In order to better perceive the difference in enhancing, enlarged segments of the images of Fig. 4 & 5 are shown in Fig. 6. The performance of the proposed method is analyzed by the variation of PSNR, BIQI Index, and VIF index of different images. Table 1, Table 2, and Table 3 give the performance comparison of the proposed and existing enhancing techniques in terms of PSNR, VIF, and BIQI index respectively. The results indicate that the proposed technique is better than the other methods in enhancing.

In this study, an efficient method is proposed for image resolution enhancement. The essence of the proposed work is the use of UDDWT for enhancement. The critically sampled discrete wavelet transform (DWT) have the drawbacks of shift variance, aliasing and lack of directionality. The DDWT is an improvement upon the critically sampled DWT and also nearly shift-invariant transform capturing directional information. Although the DDWT utilizes more wavelets, some lack a dominant spatial orientation, which prevents them from being able to isolate those directions. The UDDWT making the image exactly shift-invariant. The proposed method constructs a high resolution (HR) image from the given low resolution (LR) image by using forward and inverse UDDWT. The edge enhanced by using UDDWT. Future work may include enhancement of brightness by using Singular Value Decomposition (SVD).

Methods/ Images	Lena	Elaine	Baboon	Peppers
Bilinear	26.34	25.38	20.51	25.16
Bicubic	26.86	28.93	20.61	25.66
NEDI [1]	28.81	29.97	21.18	28.52
HMM [7]	28.86	30.51	21.47	29.58
DWT SR [8]	34.79	32.73	23.29	32.19
DWT & SWT SR [9]	34.82	35.01	23.87	33.06
SWT & LWT [10]	34.91	34.95	28.92	36.10
Proposed	40.32	42.78	34.06	39.76

TABLE 1: Comparison of PSNR in dB.

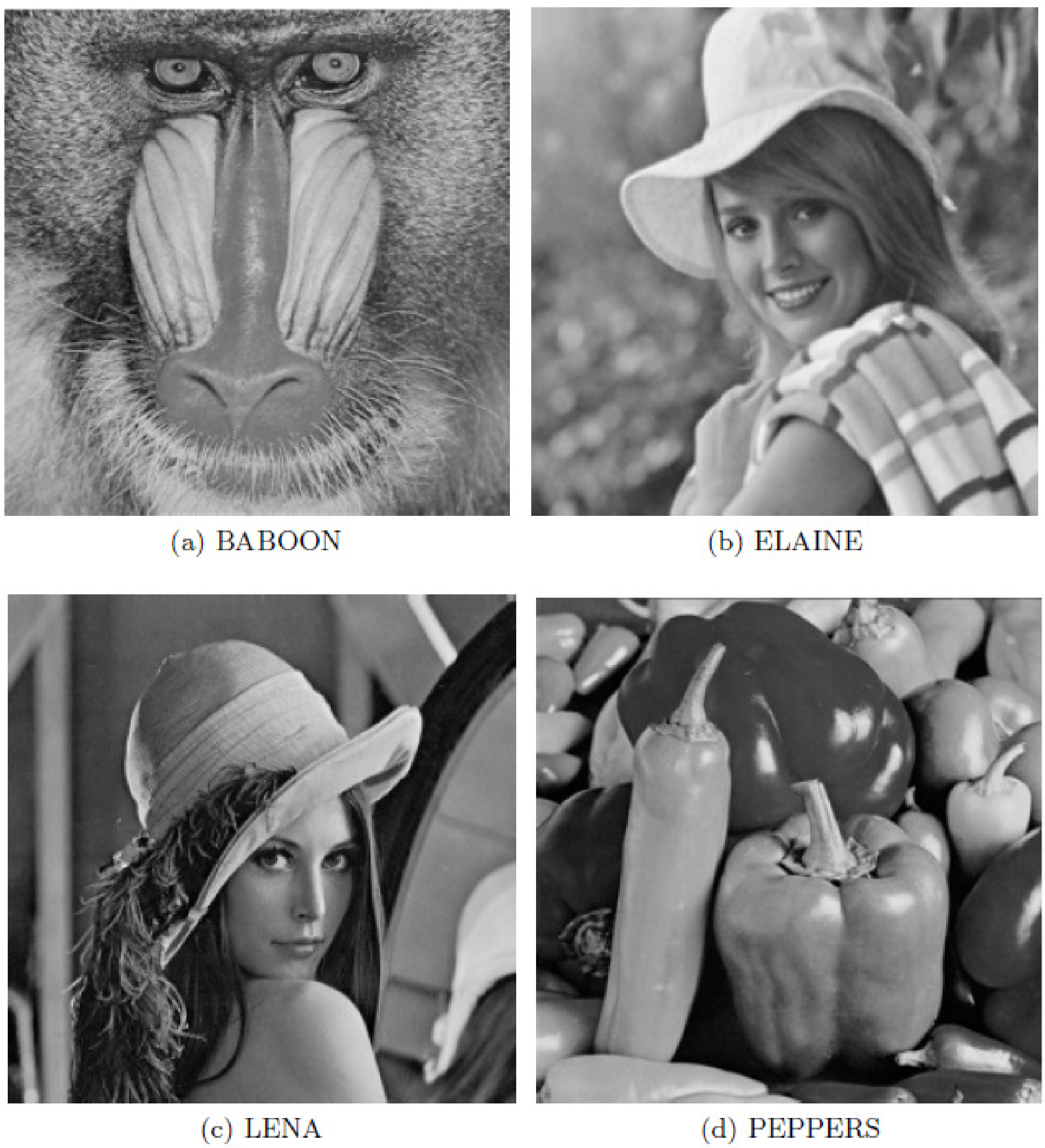


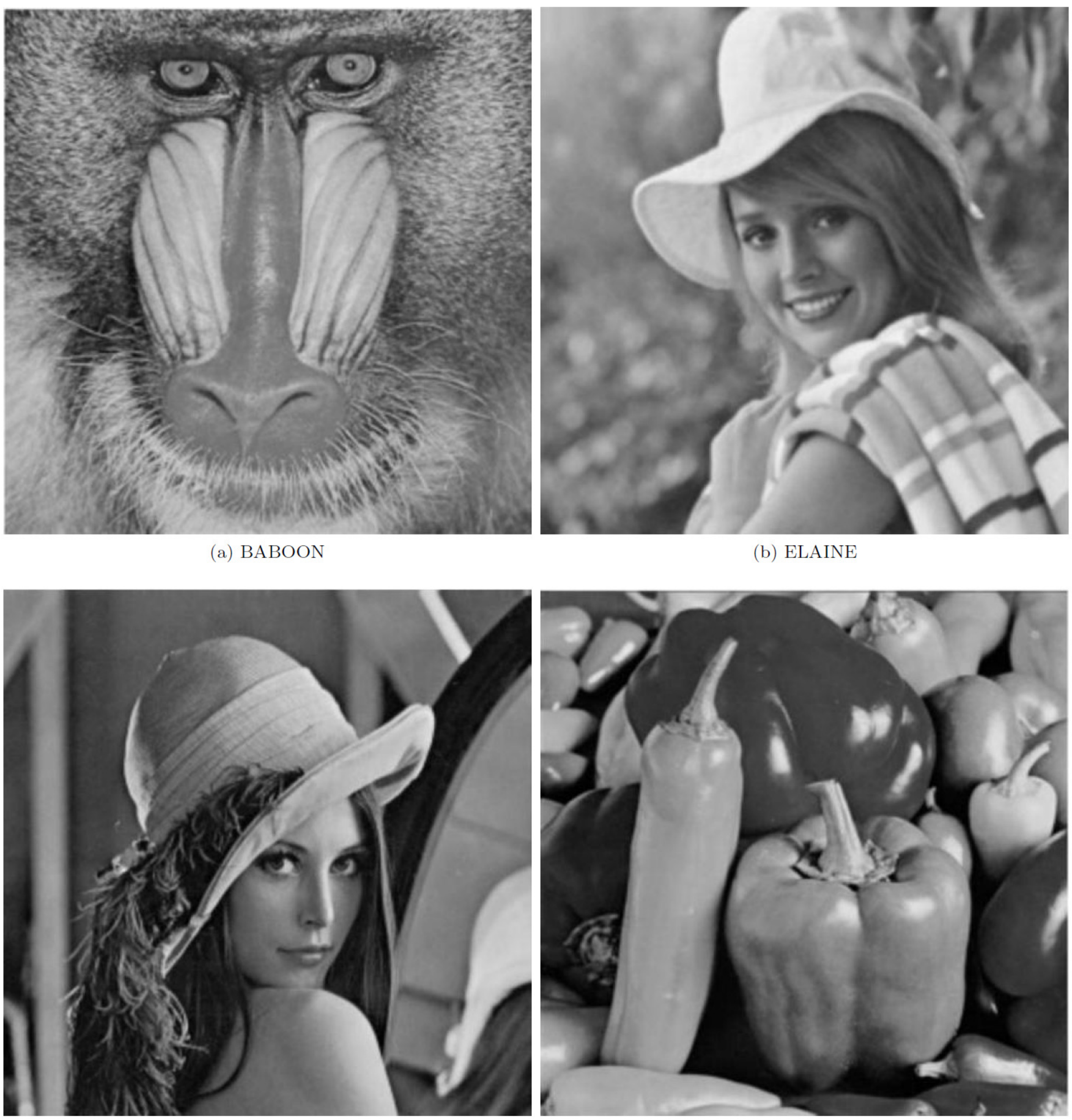
FIGURE 4: Low resolution test images.

Methods/ Images	Lena	Elaine	Baboon	Peppers
DWT & SWT SR [9]	0.14	0.19	0.17	0.19
SWT & LWT [10]	0.57	0.72	0.49	0.83
Proposed	0.67	0.71	0.51	0.85

TABLE 2: Comparison of VIF

Methods/ Images	Lena	Elaine	Baboon	Peppers
DWT & SWT SR [9]	28.21	34.02	46.09	34.37
SWT & LWT [10]	48.67	49.06	55.67	39.65
Proposed	51.24	52.85	58.43	43.42

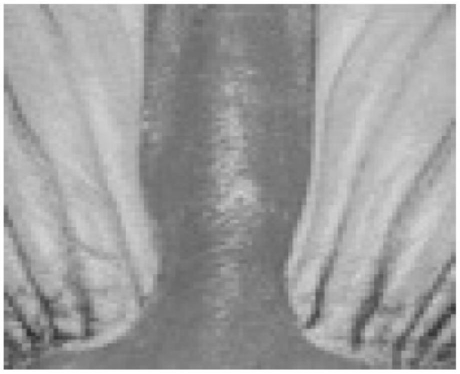
TABLE 3: Comparison of BIQI.



(a) BABOON (b) ELAINE

(c) LENA (d) PEPPERS

FIGURE 5: Resolution Enhanced images.



(a) BABOON-LOW RESOLUTION

(b) BABOON-HIGH RESOLUTION

(c) ELAINE-LOW RESOLUTION

(d) ELAINE-HIGH RESOLUTION

(e) LENA-LOW RESOLUTION

(f) LENA-HIGH RESOLUTION

(g) PEPERS-LOW RESOLUTION

(h) PEPPERS-HIGH RESOLUTION

FIGURE 6: Enlarged segments of the images of Fig. 4 & 5

6. CONCLUSION

The proposed method describes a new technique in image resolution enhancement. The technique enhances the resolution of the image by using Undecimated Discrete Wavelet Transform. The method uses a forward and inverse UDDWT to construct a high-resolution (HR) image from the given LR image. UDDWT also has nine sub bands similar to DDWT but sub bands in UDDWT are of same size of that of the image. The High Resolution image is reconstructed from the LR image using the inverse DDWT. This method is tested by using four well known images. The performance comparison shows that the proposed method is better than other enhancement methods.

7. REFERENCES

[1] X. Li and M. Orchard, "New edge-directed interpolation", IEEE Trans. Image Process., vol. 10, no. 10, pp. 1521-1527, Oct. 2001.

[2] L. Zhang and X. Wu, "An edge-guided image interpolation algorithm via directional filtering and data fusion", IEEE Trans. Image Process., vol. 15, no. 8, pp. 2226-2238, Aug. 2006.

[3] W. K. Carey, D. B. Chuang, and S. S. Hemami, "Regularity-preserving image interpolation", IEEE Trans. Image Process., vol. 8, no. 9, pp. 1293-1297, Sep. 1999.

[4] S. Chang, Z. Cvetkovic, and M. Vetterli, "Locally adaptive wavelet-based image interpolation", IEEE Trans. Image Process., vol. 15, no. 6, pp. 1471-1485, Jun. 2006.

[5] K. Kinebuchi, D. D. Muresan, and T. W. Parks, "Image interpolation using wavelet-based hidden Markov trees", inProc. IEEE Int. Conf. Acoust., Speech, Signal Process., 2001, pp. 1957-1960.

[6] A. Temizel and T. Vlachos, "Wavelet domain image resolution enhancement using cycle-spinning", Electron. Lett., vol. 41, no. 3, pp. 119-121, Feb. 2005.

[7] K. Kinebuchi, D. D. Muresan, and R. G. Baraniuk, "Wavelet based statistical signal processing using hidden Markov models", in Proc. Int. Conf. Acoust., Speech, Signal Process., 2001, vol. 3, pp. 7–11.

[8] G. Anbarjafari and H. Demirel, "Image super resolution based on interpolation of wavelet domain high frequency subbands and the spatial domain input image", ETRI J., vol. 32, no. 3, pp. 390–394,Jun. 2010.

[9] H. Demirel and Gholamreza Anbarjafari, "Image Resolution Enhancement by Using Discrete and Stationary Wavelet Decomposition", IEEE Trans. Image Procss., vol. 20, no. 5, 1458-1460, May 2011.

[10] Mayank Agrawal, Ratnakar Dash, "Image Resolution Enhancement using Lifting Wavelet and Stationary Wavelet Transform", Int. Conf. on Electronic Sys. , Signal Process. and Comput. Tech., pp.322-325, Jan. 2014.

[11] Rao Raghuveer M, Bopardikar Ajit S, "Wavelet transforms: introduction to theory and applications", Addison Wesley Longman Inc.; 1998. p. 151-66.

[12] Daubechies I. "Ten lectures on wavelets", Philadelphia: SIAM; 1992.

[13] Daubechies I. "The wavelet transform; time-frequency localization and signal analysis", IEEE Trans Inform Theory 1990;36:961-1005.

[14] Selesnick IW, Sendur L, “Iterated over sampled filter banks and wavelet frames, In: Wavelet applications VII”, proceedings of SPIE; 2000.

[15] A K Moorthy and A C Bovik, “A two-step framework for constructing blind image quality indices”, IEEE Signal Process. Lett. vol. 17 no. 5, pp. 513–516, 2010.

[16] H. R. Sheikh and A. C. Bovik, “Image information and visual quality”, IEEE Trans. Image Process., vol. 15, no. 2, pp. 430–444, Feb. 2006.