International Journal of Engineering &Technology, 7 (4) (2018) 6711-6714

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.16833
Research paper

Image enhancement technique using lifting and stationary wavelet transforms and contrast limited adaptive histogram equalization

T.V. Hyma Lakshmi [1] *, T.Madhu [2], K.Ch. Sri Kavya [3]

[1] *Research Scholar, Department of ECE, K L University (Koneru Lakshmaiah Education Foundation), AP, India*
[2] *Principal, Swarnandhra Institute of Engineering & Technology, Naraspur ,A.P., India*
[3] *Professor and Director (Engineering – PG), K L University (Koneru Lakshmaiah Education Foundation), AP, India*
**Corresponding author E-mail: tvhymalakshmi@gmail.com*

Abstract

This paper presents a new image enhancement technique which includes both resolution enhancement and contrast enhancement. In this proposed method Stationary Wavelet Transform (SWT) is used in combination with Lifting Wavelet Transform (LWT) for resolution enhancement and SWT with the combination of Contrast limited adaptive histogram equalization (CLAHE) for contrast enhancement. SWT is used in combination with LWT improves the resolution and also minimize the execution time drastically than existing methods and SWT is used in combination with CLAHE to enhance the contrast and mitigate the noise effects than existing methods. The proposed method gives superior results than existing techniques and it is proved with PSNR, Noise Estimation and RMSE and visual results.

Keywords: *Contrast Limited Adaptive Histogram Equalization (CLAHE); Lifting Wavelet Transform (LWT); Stationary Wavelet Transform (SWT); Bi-Cubic Interpolation; Peak Signal to Noise Ratio (PSNR); Weighted Average.*

1. Introduction

Image enhancement means to improve the image quality so that enhanced image looks better than the original image. Resolution enhancement [1] and contrast enhancement [2] both are important features in image processing and video processing applications, such as remote sensing, bio-medical image processing etc. [3]
Resolution is the ability of image to show its details. Hassan Demirel and Gholamreza Anbarjafari proposed the method [4] of image resolution enhancement using DWT . This method decomposes the image using DWT, and high frequency components are bi-cubic interpolated. However in this method noise has its significant effect. To mitigate noise increment they introduced SWT as an intermediate stage and proposed the method [5] of image resolution enhancement using DWT and SWT.
Contrast enhancement is an improvement of image quality to better and more understandable level for feature extraction or image interpretation. Contrast enhancement techniques have been classified into two principle groups: spatial-domain, transform-domain based methods. Spatial domain techniques like logarithmic transforms, power law transform, histogram equalization methods are based on direct manipulation of pixels in the image plane, while transform domain techniques are based on the manipulation of the transform of the image rather than the image itself. Histogram equalization is a method of contrast adjustment [6] using the image histogram in image processing. This method increases the global contrast of images by applying a gray level transform which tries to flatten the resulting histogram. Histogram equalization works best on over or under exposed image, which has narrow contrast range. Since the HE is applied on the whole image, the local details are not enhanced effectively. To overcome these drawbacks, local histogram equalization (LHE) based methods are proposed.
Pizer [7] proposed the contrast limited adaptive histogram equalization (CLAHE) which is an LHE-based image enhancement method. Histograms that are above the clip limit are clipped and distribute to the other histograms of different regions which have histogram height below the clip limit. In transform-domain based methods decomposition is applied i.e. transformed into frequency domain before image enhancement, which prevents image artifacts and improves image quality. Huang lidong proposed [8] CLAHE-DWT method which is one of the contrast enhancement method and uses the combination of both DWT and CLAHE. Drawbacks of CLAHE are overcome by this CLAHE-DWT method.
In this paper, we introduce a new contrast and resolution enhancement technique which can improve resolution, contrast of image and avoid over enhancement, reduce the noise effects and also improve the execution speed. This new method combines SWT with LWT and CLAHE with SWT. In this proposed method input image is given to both LWT and SWT for resolution increment. Bi-cubic interpolation is used for sharper details. Resolution enhanced image is given to SWT for different frequency subbands. SWT minimize the loss in terms of down sampling. CLAHE is applied to low frequency components only to improve the contrast of the low frequency components. This mitigates the effect of noise during process of contrast enhancement. Finally inverse LWT gives contrast enhanced image. Noise effect can be further decreased by taking the average of original image and output of inverse wavelet transform.

2. Related work

This proposed method uses the combination of LWT-SWT for resolution enhancement and CLAHE-SWT for contrast enhancement. First, input image of size [256×256] is decomposed using both LWT and SWT using Haar mother wavelet to get the low-frequency components and high-frequency components individually. The Haar wavelet is the simplest wavelet of all other wavelet families in terms of computation of wavelet coefficients. Fig. 1 shows the flow chart of proposed method. LL, LH, HL and HH are sub-band images obtained by applying LWT. In this section we provide the work which is related to proposed method that is about CLAHE and CLAHE-DWT.

2.1. Lifting wavelet transform

Lifting wavelet transform was introduced by Wim Sweldens. It factorizes orthogonal and biorthogonal wavelet transforms into elementary spatial operators called lifting. It has two main applications. The first one is an acceleration of the fast wavelet transform algorithm. The filter bank convolution and sub-sampling operations are factorized into elementary filtering on even and odd samples, which reduces the number of operations by nearly 2[9][10]. Border treatments are also simplified. This is also called a Para-unitary filter bank implementation. The second application is the design of wavelets adapted to multidimensional bounded domains and surfaces, which is not possible with a Fourier transform approach.

2.2. Perfect reconstruction

As Every transform by the lifting scheme can be inverted. Every perfect reconstruction filter bank can be decomposed into lifting steps by the Euclidean algorithm. That is, "lifting decomposable filter bank" and "perfect reconstruction filter bank" denotes the same.

2.3. Speedup by a factor of two

This is only possible because lifting is restricted to perfect reconstruction filter-banks. That is, lifting somehow squeezes out redundancies caused by perfect reconstruct ability. In place: The transformation can be performed immediately in the memory of the input data with only constant memory overhead.

2.4. CLAHE

The main steps of CLAHE are given as follows

1) Divide the input image into tiles.
2) Set the clip limit, clip the histograms above clip limit and redistribute to other sub-blocks.
3) Apply histogram equalization to the each tile.
4) Interpolate the neighboring tiles.

Selection of tile size and clip limit is crucial for CLAHE because these parameters mainly control image quality. These parameters of CLAHE [11] are determined based on image entropy. Image entropy is proportional to the distribution of histogram. Selection of tile size and clip limit follows [12] the below steps.

1) Set tile size as [8 8], vary the clip limit and apply CLAHE to input image.
2) Find entropy of CLAHE output, maximum entropy gives the best clip limit.
3) Update the above obtained clip limit, now vary the tile size from [2 2] to [32 32].
4) Repeat the step 2, maximum entropy gives the best tile size.
5) Update the tile size with value obtained above and performs the CLAHE with these parameters.

Discrete entropy is defined as [13] follows

$$H(x) = -\sum_{i=1}^{N} P(x_i)\log_2 p\,(x_i) \quad (1)$$

CLAHE-DWT: This method uses the combination of CLAHE and DWT to eliminate the drawbacks of CLAHE. Applying CLAHE to low-frequency components only reduces the noise. [14] The Weighted average of the original image and reconstructed image alleviates the contrast overstretching. Pixels with higher intensities are enhanced less because of proportionality of weighting factor with pixel intensities. Choosing of weighting factor has significance and it is selected based on local entropy increment (LEI).
This proposed method uses the combination of DWT-SWT for resolution enhancement and CLAHE-SWT for contrast enhancement. First, input image of size [256×256] is decomposed using both DWT and SWT using Haar mother wavelet to get the low-frequency components and high-frequency components individually. The Haar wavelet is the simplest wavelet of all other wavelet families in terms of computation of wavelet coefficients. Fig. 1 shows the flow chart of proposed method.

3. Proposed method

This proposed method uses the combination of DWT-SWT for resolution enhancement and CLAHE-SWT for contrast enhancement. First, input image (Fig.2a, 3a) of size [256×256] is decomposed using both DWT and SWT using Haar mother LL, LH, HL and HH are sub-band images obtained by applying LWT. LL is the low-frequency information obtained by applying low pass filters and it is the approximation of original image with half size of the original image. LH, HL and HH are the vertical, horizontal and diagonal information respectively. LL1, LH1, HL1 and HH1 are the sub-band images obtained after applying SWT. The SWT is used to reduce the pixel loss and high frequency sub-bands of LWT are interpolated with factor 2 with the help of bi-cubic interpolation. Bi-cubic interpolation method uses the weighted average of neighboring sixteen pixels to estimate the intensity value of the middle pixel. This method gives excellent results both in calculation speed and quality of transformed image. Interpolation increases the number of pixels in a given image. High frequency sub-bands of SWT and interpolated sub-bands of LWT are combined. By taking the Inverse LWT of low frequency sub-band and new sub-bands we get the high resolution image with size [512×512].Now the image is resolution enhanced but contrast of image is still poor .To improve the contrast of image ,CLAHE techniques is used on the resolution enhanced image. First Resolution enhanced image is given to SWT.SWT is preferred because of its self-property of no down sampling and LWT improves the speed of operation, this is the main advantage of SWT over DWT in terms of pixel loss. Now, CLAHE is applied to low frequency sub-band. This is because high frequency sub-bands contains most of noise and by applying CLAHE to these sub-bands also causes noise increment. Because of this CLAHE is applied to low frequency sub-bands only. By taking the Inverse transform of CLAHE applied sub-band and high frequency bands we get high contrast image with size [512×512].On taking the average of low contrast image and resultant of Inverse transform noise can be further be reduced. Finally resultant images are both resolution enhanced and contrast enhanced images shown in fig 2 and 3. Proposed techniques is compared with existing techniques with visual results and quantitative results in table 1 and 2 using noise estimation and peak signal to noise ratio. [15]
NOISE ESTIMATION (NE): It is used to measure the noise amplification during the process of resolution enhancement and contrast enhancement. For the estimation of noise, noise is added to input image with mean zero and with a variance of 2.56. Table 1 and Table 2 give the PSNR, RMSE, NE values of color image and gray scale image respectively.

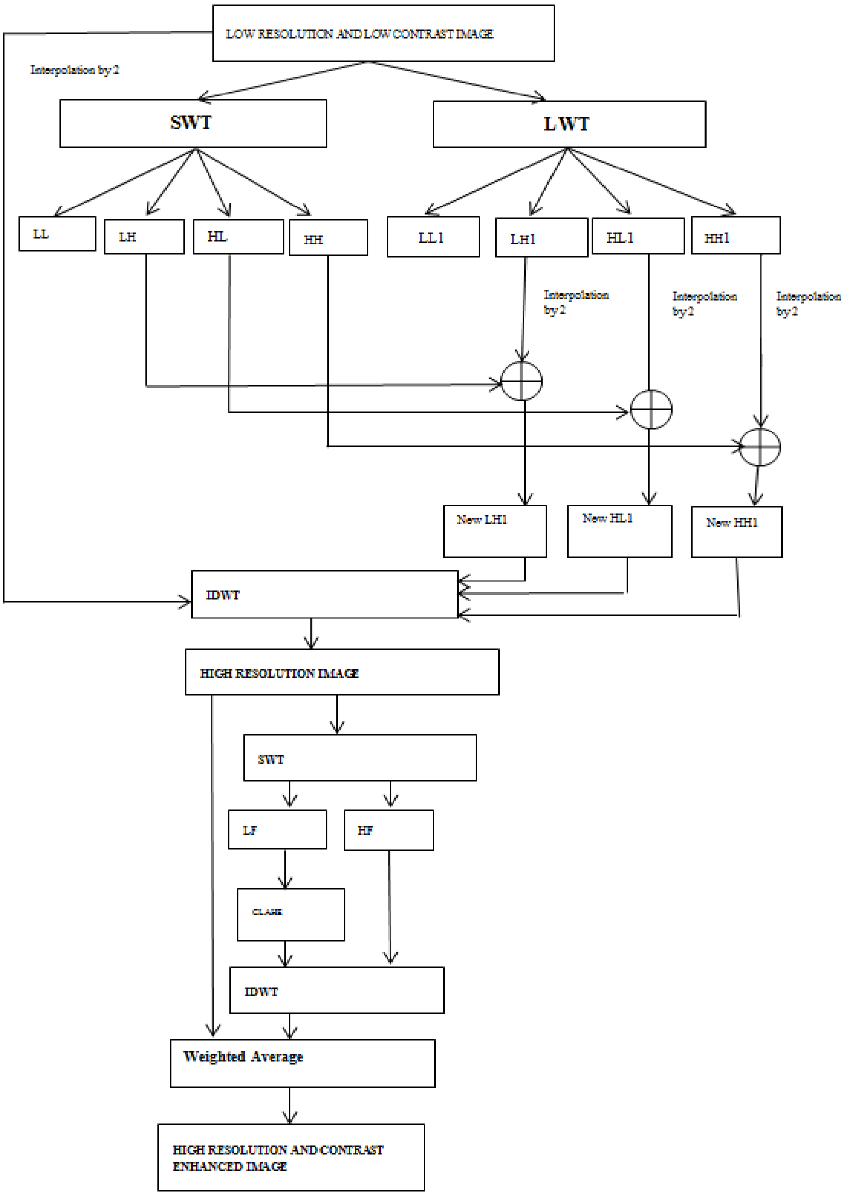

Fig. 1: Flow Chart of LWT-SWT & CLAHE-SWT (Proposed Method).

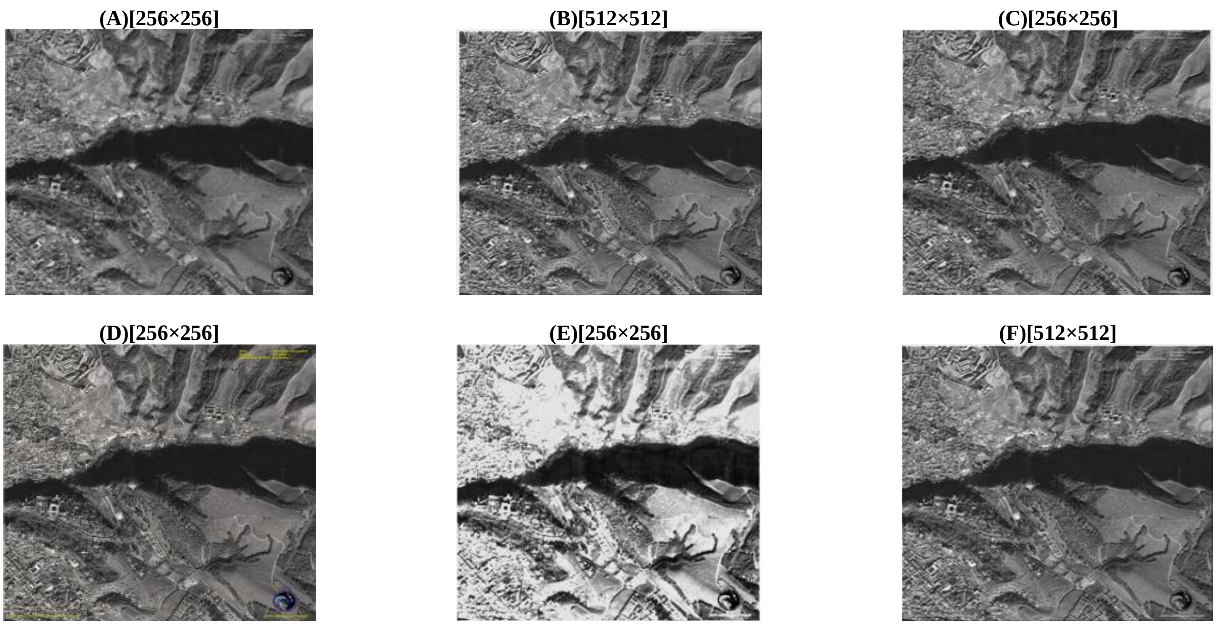

Fig. 2: Gray Scale Satellite Image. A) Original Image (B) Dwt-Swt C) Histogram Equalization D) Clahe E) Clahe-Dwt and F) Proposed Method.

Fig. 3: Wall Image. A) Original Image B) Dwt-Swt C) Histogram Equalization D) Clahe E) Clahe-Dwt and F) Proposed Method.

Table 1: Comparison of Proposed Method with Other Methods Using Color Image (Input Image Size Is 256X256X3)

(WALL IMAGE)	PSNR(dB)	NE(σ)	RMSE	Output image size
HE	45.5744	0.1163	0.0841	512X768X3
CLAHE	44.9695	0.1310	0.0902	512X768X3
CLAHE-DWT	47.0412	0.0991	0.0894	512X768X3
DWT&SWT	41.87	0.166	0.1287	1024X1024X3
Proposed Method	52.7290	0.0290	0.0464	1028X1540X3

Table 2: Comparison of Proposed Method with Other Methods Using Gray Scale Satellite Image (Input Image Size Is 256X256)

(LIVING ROOM IMAGE)	PSNR(dB)	NE(σ)	RMSE	Output image size
HE	55.7288	0.1692	0.4170	256X256
CLAHE	56.0284	0.2058	0.4028	256X256
CLAHE-DWT	56.2795	0.1613	0.3917	256X256
DWT&SWT	44.96	0.266	0.0902	1024X1024
Proposed Method	57.6159	0.0634	0.0765	1032X1032

4. Conclusion

In this paper we proposed a novel image resolution and contrast enhancement method, which combine the LWT-SWT with CLAHE-SWT. In this method the image is decomposed into sub-bands by both LWT and SWT. The high frequency sub-bands of LWT are interpolated and combined with high frequency sub-bands of SWT. This increases the resolution of image .CLAHE is applied to only low-frequency sub-bands of SWT. This reduces the effect of noise. Visual results and quantitative results (PSNR, NE, RMSE) show that proposed method performs better than the existing methods.

References

[1] T.V. Hyma Laksmi, T.Madhu, E.V.Krishna Rao, V. Lakshmimounica, "Satellite Image Resolution Enhancement Using Discrete Wavelet transform and Gaussian Mixture Model", irjet, vol.2,issue no.4, July 2015, Pages: 95-101.

[2] T.V. Hyma Laksmi, T.Madhu, E.V.Krishna Rao, K.Ch. Sri Kavya , "Satellite Image Resolution Enhancement Using Non Decimated Wavelet transform and Gaussian Mixture Model", International Journal of Applied Engineering Research, vol.10,issue no.19, 2015, Pages: 40746-40753

[3] T.V. Hyma Laksmi, T.Madhu, K.Ch. Sri Kavya , A.Geetha Devi "Image Resolution and Contrast Enhancement Using Wavelet transforms and Contrast Limited Adaptive Histogram Equalization", International Journal of Computer Science and Information Security, vol.14, Issue no.9, September 2016, Pages: 969-981.

[4] Hassan Demirel and Gholamreza Anbarjafari, "Discrete Wavelet Transform-Based Satellite Image Resolution Enhancement," IEEE Trans. on geoscience and remote sensing, vol. 49, Issue.6, June 1993. https://doi.org/10.1109/TGRS.2010.2100401.

[5] Hassan Demirel and Gholamreza Anbarjafari. "Image resolution enhancement by using discrete and stationary wavelet decomposition", IEEE transactions on image processing may 2011. https://doi.org/10.1109/TIP.2010.2087767.

[6] Abdulla-al-Wadud,Md Hassanul Kabir "A Dynamic histogram equalization for image contrast enhancement", IEEE transaction on consumer electronics , Volume:53, issue 2, 2007. https://doi.org/10.1109/TCE.2007.381734.

[7] S. M. Pizer, E. P. Amburn, J. D. Austin, "Adaptive Histogram Equalization and Its Variations", Computer Vision, Graphics, and Image Processing Vol.39 (1987) 355-368. https://doi.org/10.1016/S0734-189X(87)80186-X.

[8] Byong Seok Min, Dong Kyun Lim, Seung Jong Kim and Joo Heung Lee, "A novel method of determining CLAHE based on image entropy", International Journal of Software Engineering and Its Applications, Vol.7, No.5 (2013), pp.113-120. https://doi.org/10.14257/ijseia.2013.7.5.11.

[9] Patel Hardik Anilkumar and P. Augusta Sophy Beulet, "Lifting-based Discrete Wavelet Transform for Real-Time Signal Detection", Indian Journal of Science and Technology, Vol 8(25), October 2015. https://doi.org/10.17485/ijst/2015/v8i25/80301.

[10] Prateek Mehrotra and Siddhartha, "Fuzzy Based Image Enhancement through Lifting Wavelet Transform", 3rd International Conference on System Modeling & Advancement in Research Trends, 2014.

[11] C. Wang and Z. Ye, "Brightness Preserving Histogram Equalization with Maximum Entropy: A Variational Perspective", IEEE Trans. on Consumer Electronics, vol. 51, no. 4, (2005), pp. 1326-1334. https://doi.org/10.1109/TCE.2005.1561863.

[12] D. P. Sharma "Intensity Transformation using Contrast Limited Adaptive Histogram Equalization" International Journal of Engineering Research (ISSN: 2319-6890) Volume No.2, Issue No. 4, pp: 282-285 01 Aug. 2013

[13] Huang lidong, zhaowei, wangjun, sun zebin, "Combination of contrast limited adaptive histogram equalization and discrete wavelet transform for image enhancement", The institution of engineering and technology,2015 vol. 9,issue10,pp 908-915. https://doi.org/10.1049/iet-ipr.2015.0150.

[14] T.V. Hyma Laksmi, T.Madhu, K.Ch. Sri Kavya ,Shaik. EsubBasha "Novel Image Enhancement Technique Using CLAHE and Wavelet transforms", IJSET,vol.5,issue no.6, November 2016, Pages: 507-511. https://doi.org/10.17950/ijset/2016v5s11/1103.

[15] T.V. Hyma Laksmi, T.Madhu, K.Ch. Sri Kavya , "Half-Band Polynomial Sub Bands Fusion and CLAHE", Journal of Advanced Research in Dynamical & Control Systems,vol.10,issue no.4, 2018, Pages: 333-338.