TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 8595 - 8602

Efficient Wavelet related Transforms in Image Denoising

Prabhishek Singh[1], Chandrakala Arya[2], Kanika Sharma[3], Manoj Diwakar[4]*, Shilpi Singh[5]

[1]Department of CSE, Amity School of Engineering and Technology, Amity University Uttar Pradesh, Noida, India Email: prabhisheksingh88@gmail.com

[2]Department of School of Computing, Graphic Era Hill University, Dehradun, Uttarakhand, India, Email:

arya.chandrakala@gmail.com

[3]Department of IT, IMS Noida, India, Email: sharma.kanika247@gmail.com

[4]Department of CSE, Graphic Era (Deemed to be University) Dehradun, Uttarakhand, India, Email:

manoj.diwakar@gmail.com

[5] Department of CSE, Amity School of Engineering and Technology, Amity University Patna, India, Email: shilpi.singh.it@gmail.com

Article Info
Volume 83
Page Number: 8595 - 8602
Publication Issue:
May - June 2020

Article History
***Article Received**: 19 November 2019*
***Revised**: 27 January 2020*
***Accepted**: 24 February 2020*
***Publication**: 18 May 2020*

Abstract:

Noise corrupts the image during acquisition and transmission phase. It degrades the quality of the image due to which some important information gets lost. Image denoising is the process of reducing the noise from the noisy image and enhancing the quality of the image while preserving the important details of the image like edges, corners, structure and texture. There are many conventional filters and algorithms available to denoise the noisy images in spatial and frequency domain. This paper focuses on one of the most adaptive and efficient platform where any number of efficient denoising schemes can be developed, i.e. wavelet transform. This is an old concept, but still in much use due to its easy and adaptive behavior. A lot of standard modifications have been done in wavelet transform. This paper briefly introduces those wavelet transforms which are highly efficient in the field of image denoising and also introduces some extended versions of the wavelet which are very popular in the field of image processing and scientific computing. The main motive of this paper is to provide research awareness about the various wavelet transforms in image denoising.

Keywords— image denoising; wavelet transform ; DWT; curvelet transform

May – June 2020
ISSN: 0193-4120 Page No. 8595 - 8602

I. Introduction

Image denoising is one major field of research in image processing. Noise is the major concern which corrupts the image during acquisition and transmission process. Denoising is the process of removing the noise from the image while maintaining the quality of the image. The conventional approach of image de-noising is filtering. In recent times, a lot of research about linear and non-linear methods of image de-noising has been developed.

Donoho and Johnstone [12]-[15] did the pioneer work in the wavelet domain by defining the threshold levels and their type (i.e. hard or soft threshold). Matlab wavelet toolbox contains inbuilt-functions for 1-D or 2-D de-noising [16], which works on the concept of Donoho's projected thresholds. However, in the 2-D case, there is no possibility for the choice of a threshold measure and the threshold is not level dependent. In this work, major wavelet related transforms are discussed which works efficiently in the domain of image denoising. According to the proposed work, among all other wavelet transforms, DWT is one of the mostly used, simple, interesting, adaptive and efficient transform to work upon [24]. There is a lot of scope to develop new schemes using this transform not only in image denoising but also in other areas. G. Ghodrati Amiri and A. Asadi presented a paper on Comparison of Different Methods of Wavelet and Wavelet Packet Transform in Processing Ground Motion Records [17]. Palle E. T. Jorgensen, Myung-Sin Song proposed a review report on comparison of discrete and continuous wavelet transforms [18], [24]. Gaoyong Luo presented a work on fast wavelet transform for explaining Fast Wavelet Image Denoising Based on Local Variance and Edge Analysis [19]. Vandana Roy and Shailja shukla worked on the Spatial and Transform Domain Filtering Method for Image De-noising: A Review [20]. Burhan Ergen [3] prepared a detailed research paper on Signal and Image Denoising Using Wavelet Transform where detailed denoising of image and signal is discussed. Abdullah Al Jumah [9] discussed on Denoising of an Image Using Discrete Stationary Wavelet Transform and Various Thresholding Techniques. Nick Kingsbury [21] describes a form of discrete wavelet transform, which generates complex coefficients by using a dual tree of wavelet filters to obtain their real and imaginary parts in the paper entitled "Complex Wavelets for Shift Invariant Analysis and Filtering of Signals". The work in [23] describes the statistical approach of applying the DWT on log transformed speckled image.

The article contains three sections: Section I introduces the image denoising and also presents the major literature in the image and signal denoising. Section II briefly describes various wavelet related transforms in image denoising and last section concludes the paper.

II. Wavelet related Transforms

A. Continuous wavelet transform

Continuous wavelet transform (CWT) that provides more consistent and thorough time-scale representation rather than the traditional short time Fourier transform (STFT) giving a time-frequency depiction [1], [2].

The CWT is figured by altering the scale of the mother wavelet, shifting the scaled wavelet in time, multiplying by the signal, and integrating over all times [3]. When the signal to be examined and wavelet function

May – June 2020
ISSN: 0193-4120 Page No. 8595 - 8602

are discredited, the CWT can be comprehended on computer and the totaling time can be significantly reduced if the redundant samples removed respect to sampling theorem. This is not a true discrete wavelet transform (DWT) [3].

B. *Discrete wavelet transform*

The practice of wavelet transform as filter bank named as DWT (Discrete Wavelet Transform) [25]. The DWT of a signal and image yields a non-redundant restoration, which provides better spatial and spectral localization of signal formation, compared with other multi-scale depiction such as Gaussian and Laplacian pyramid [3]. The consequence of the DWT is a multilevel decomposition, in which the signal is decomposed into approximation (LL) and detail (HL, LH and HH) coefficients at each level [4]. This is made through a process that is equivalent to low-pass and high passes filtering, respectively [3], [5].

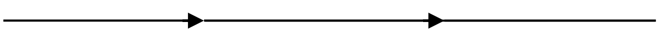


Fig 1. 2D-DWT decomposition up to two level

Before implementing DWT on image in denoising, there is couple of points to be noted down. First of all, wavelet family basis is desired to be selected for each decomposition layer like, db2, haar etc [6]. Secondly, level of decomposition is desired to be decided. Although in image denoising, image can be decomposed up to any level, but it is seen in most of the cases that the denoising outcomes are finest at 3-5 level. Wavelet based denoising is performed by following three steps:

Step 1: Perform DWT on input denoised image to get approximate and detail parts.

Step 2: Perform the denoising using following steps:

i. Estimate noise variance.

ii. Calculate threshold.

iii. Apply thresholding on detail parts.

Step 3: Apply inverse DWT to obtain final denoised image.

C. *Fast wavelet transform*

The Fast Wavelet Transform (FWT) is a mathematical algorithm developed to turn a waveform or signal in the time domain into a sequence of coefficients based on an orthogonal basis of small finite waves, or wavelets. The transform can be easily stretched to multidimensional signals, such as images, where the time domain is exchanged with the space domain. It has as theoretic basis the device of a finitely generated, orthogonal multiresolution analysis (MRA).

FWT returns discrete wavelet coefficients of the input signal f using J iterations of the basic wavelet filter bank defined by w using the fast wavelet transform algorithm [5]. The coefficients are the DWT of the input signal f, if w defines two-channel wavelet filter bank.

D. *Dual-tree complex wavelet transform*

For few applications of the DWT, enhancements can be attained by using an expansive wavelet transform in place of a critically-sampled one. (An expansive transform is that which converts an N-point signal into M coefficients where M > N.) There are several kinds of expansive DWTs; here we describe the dual-tree complex discrete wavelet transform [7].

The transform is 2-times expansive because for an N-point signal it gives 2N DWT coefficients. If the filters in the upper and lower DWTs are the same, then no benefit is gained [7]. However, if the filters are designed is a specific way, then the sub band signals of the upper DWT can be interpreted as the real part of a complex wavelet transform, and subband signals of the lower DWT can be interpreted as the imaginary part. Equivalently, for specially designed sets of filters, the wavelet associated with the upper DWT can be an approximate Hilbert transform of the wavelet associated with the lower DWT. When designed in this way, the dual-tree complex DWT is nearly shift-invariant, in contrast with the critically-sampled DWT [7]. Moreover, the dual-tree complex DWT can be used to implement 2D wavelet transforms where each wavelet is oriented, which is especially suitable for image processing. (For the separable 2D DWT, recall that one of the three wavelets does not have a dominant orientation) [26]. The dual-tree complex DWT outperforms the critically-sampled DWT for applications like image denoising and enhancement [7].

E. Stationary wavelet transform

The Stationary wavelet transform (SWT) is a wavelet transform algorithm aimed to overcome the lack of translation-invariance of the DWT [8]. The SWT is an inherently redundant scheme as the outcome of each level of SWT holds the same number of samples as the input – so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients [27].

For the SWT scheme the output signals at each stage are redundant because there is no signal down sampling; insertion of zeros between taps of the filters is used instead of decimation [9].

F. Complex wavelet transform

The critically sampled DWT has been effectively implemented to a broad range of signal processin

g tasks. However, its performance is limited because of the following problems [10]: Oscillations, Shift variance, Aliasing and Lack of directional selectivity [29].

To overcome the shift dependence problem, we can exploit the undecimated DWT, however, without solving the directional selectivity problem. Another approach is inspired by the Fourier transform, whose magnitude is shift invariant and the phase offset encodes the shift [11]. In such a wavelet transform, a large magnitude of a coefficient implies the presence of a singularity while the phase signifies its position within the support of the wavelet. The complex wavelet transform (CoWT) employs analytic or quadrature wavelets guaranteeing magnitude phase representation, shift invariance and no aliasing [11].

G. WITS: Where Is The Starlet

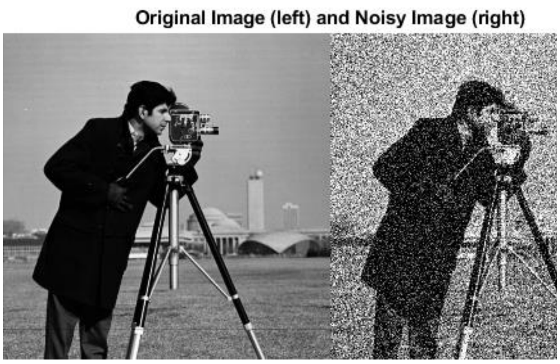
It is a collection of hundredth of wavelet names in -let and related multiscale, directional, geometric, representations, from activelets to x-lets through bandelets, shearlets, chirplets, contourlets, curvelets, ridgelets, noiselets, wedgelets etc [22]. These transforms are the extended versions of the

May – June 2020
ISSN: 0193-4120 Page No. 8595 - 8602

wavelet transforms and are highly efficient and adaptive in nature. These extended versions are highly used in the present research work. These are the extension of the wavelet concept and now they are becoming popular in fields like, image processing and scientific computing [29].

III. Experimental Comparative Analysis

The experimental testing is performed on various digital images but in this paper the denoising results are shown in the standard "cameraman" image shown in the Fig 2(a). The denoising results are calculated at the noise variance of 25% shown in the Fig 2(b). The comparative analysis is performed using these methods i.e. CWT [3], DWT [25], FWT [5], Dual Tree CoWT [7], SWT [27] and CoWT [11].



(A) (B)

Fig 2. (a) Original image (b) Noisy image (σ=25%)

The quantitative and qualitative analysis is performed on methods i.e. CWT [3], DWT [25], FWT [5], Dual Tree CoWT [7], SWT [27] and CoWT [11] as shown in Table 1 and Fig 3 respectively. The metrics used for these calculations are Peak signal to noise ratio (PSNR), Structural similarity index metric (SSIM) and Universal image quality index (UIQI). As per quantitative analysis, the SWT [27] shows the best results and out of compared methods CWT [3] shows the lowest quality results. The order of best results as per quantitative analysis is {SWT > DWT >Dual Tree CoWT > CoWT > FWT >CWT}.

Table 1. Quantitative analysis using PSNR, SSIM and UIQI

Image Denoising Methods	PSNR	SSIM	UIQI
CWT [3]	30.5091	0.8512	0.8463
DWT [25]	34.4567	0.9543	0.9601
FWT [5]	32.8132	0.8976	0.8712
Dual Tree CoWT [7]	33.4672	0.9356	0.9508
SWT [27]	35.4535	0.9862	0.9973
CoWT [11]	33.0229	0.9031	0.8981

(A)

(B)

©

(D)

(e)

(F)

Fig 3. Qualitative analysis of denoised results of denoising methods (a) CWT (b) DWT (c) FWT (d) Dual Tree CoWT (e) SWT (f) CoWT

Fig 3 shows the qualitative analysis of all compared methods. As per qualitative analysis, the fine details are well preserved in the SWT and DWT methods. The texture part of CWT and FWT are disturbed in the non-uniform regions of the image. The Dual tree CoWT and CoWT shows satisfactory results in terms of visual quality but less quality than SWT and DWT. The edges are well preserved in the DWT and SWT methods. The uniformity is also well preserved in the DWT and SWT methods. On visual comparison, the results of DWT and SWT look same but on zooming the results, the edges are well more preserved in the SWT than DWT.

IV. Conclusion

This paper briefly introduces various types of wavelet transform and various extended versions of wavelet transform. The discussed wavelet transforms are commonly used in the image denoising purpose. The others can also

May – June 2020
ISSN: 0193-4120 Page No. 8595 - 8602

be used in the same work but the best results are obtained using these transforms. Among the discussed transforms, the DWT and SWT are the mostly used transforms in the previous years due to its simple and adaptive behavior and they are still prevalent. The main motive of this paper is to provide brief research awareness regarding some wide used wavelet transforms in the field of image denoising.

References

1. Jiang, Q. "Orthogonal multiwavelets with optimum time-frequency resolution." Signal Processing, IEEE Transactions on 46(4): 830-844.
2. Qian, S. and D. Chen "Joint time-frequency analysis." Signal Processing Magazine, IEEE 16(2): 52-67.
3. Burhan Ergen, "Signal and Image Denoising Using Wavelet Transform, Advances in Wavelet Theory and Their Applications in Engineering", Physics and Technology, Dr. Dumitru Baleanu (Ed.), ISBN: 978-953-51-0494-0, InTech, Available from: http://www.intechopen.com/books/advances-in-wavelet-theory-and-theirapplications-in-engineering-physics-and-technology/wavelet-signal-and-image-denoising
4. Mallat, S. G., "A theory for multiresolution signal decomposition: The wavelet representation." Pattern Analysis and Machine Intelligence, IEEE Transactions on 11(7): 674-693.
5. Mallat, S. G., "A wavelet tour of signal processing", Academic Pr.
6. Prabhishek Singh, Raj Shree, A New Computationally Improved Homomorphic Despeckling Technique of SAR Images, International Journal of Advanced Research in Computer Science, Volume 8, No. 3, March April 2017.
7. Shihua Cai & Keyong Li, Advisor: Prof. Ivan Selesnick, Dual-Tree Complex Wavelet Transform, Matlab Implementation of Wavelet Transforms, **Available** : http://eeweb.poly.edu/iselesni/WaveletSoftware/dt1D.html
8. J.E. Fowler, "The redundant discrete wavelet transform and additive noise", Published in: IEEE Signal Processing Letters (Volume: 12, Issue: 9, Sept. 2005)
9. Abdullah Al Jumah, "Denoising of an Image Using Discrete Stationary Wavelet Transform and Various Thresholding Techniques", Journal of Signal and Information Processing, 2013, 4, 33-41, http://dx.doi.org/10.4236/jsip.2013.41004 Published Online February 2013 (http://www.scirp.org/journal/jsip)
10. I. W. Selesnick, R. G. Baraniuk, and N. G. Kingsbury. The Dual-Tree Complex Wavelet Transform. IEEE Signal Processing Magazine, 22(6):123–151, November 2005.
11. Hošťálková, Eva, and Aleš Procházka. "Complex wavelet transform in biomedical image denoising." (2007).
12. D.L. Donoho, De-noising by soft thresholding, IEEE Trans. on Info. Theory, pp. 933-936, 1993.
13. D.L. Donoho, I.M. Johnstone, Ideal spatial adaptation via wavelet shrinkage, Biometrica, vol. 81, pp. 425-455, 1994.
14. D.L. Donoho, I.M. Johnstone, Adapting to unknown smoothness via wavelet shrinkage, Journal of American statistical assoc., vol. 90, no. 432, pp. 1200-1224, 1995.
15. D.L. Donoho, I.M. Johnstone, Wavelet shrinkage: Asymptopia, J.R. Stat. Soc., series B, vol. 57, no. 2, pp. 301-369, 1995.
16. Matlab Wavelet Toolbox User's Guide, MathWorks, 1996.
17. G. Ghodrati Amiri and A. Asadi, "Comparison of Different Methods of

Wavelet and Wavelet Packet Transform in Processing Ground Motion Records", International Journal of Civil Engineering. Vol. 7, No. 4, December 2009.

18. Palle E. T. Jorgensen, Myung-Sin Song, "Comparison of Discrete and Continuous Wavelet Transforms", arXiv:0705.0150 [cs.CE].
19. Gaoyong Luo, "Fast Wavelet Image Denoising Based on Local Variance and Edge Analysis", World Academy of Science, Engineering and Technology International Journal of Computer, Electrical, Automation, Control and Information Engineering Vol:2, No:4, 2008.
20. Vandana Roy and Shailja shukla, "Spatial and Transform Domain Filtering Method for Image De-noising: A Review", I.J.Modern Education and Computer Science, 2013, 7, 41-49, Published Online September 2013 in MECS (http://www.mecs-press.org/) DOI: 10.5815/ijmecs.2013.07.05
21. Kingsbury, N G (May 2001). "Complex wavelets for shift invariant analysis and filtering of signals" (PDF). Journal of Applied and Computational Harmonic Analysis. 10 (3): 234–253. doi:10.1006/acha.2000.0343.
22. WITS = Where Is The Starlet?, Available: http://www.laurent-duval.eu/siva-wits-where-is-the-starlet.html
23. Singh, P., et al. "A new SAR image despeckling using correlation-based fusion and method noise thresholding". Journal of King Saud University – Computer and Information Sciences (2018), https://doi.org/10.1016/j.jksuci.2018.03.009
24. Prabhishek Singh, Raj Shree, "A new homomorphic and method noise thresholding based despeckling of SAR image using anisotropic diffusion", Journal of King Saud University – Computer and Information Sciences (2017), http://dx.doi.org/10.1016/j.jksuci.2017.06.006
25. P. Singh, R. Shree, "A new SAR image despeckling using directional smoothing filter and method noise thresholding", Eng. Sci. Tech., Int. J. (2018), https://doi.org/10.1016/j.jestch.2018.05.009
26. Madhu Bala Bhatt., et al., "A New Wavelet-based Multifocus Image Fusion Technique using Method Noise-Median Filtering", 2019 4th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), 18-19 April 2019, DOI: 10.1109/IoT-SIU.2019.8777615
27. Prabhishek Singh, Raj Shree, "Quantitative Dual Nature Analysis of Mean Square Error in SAR Image Despeckling", International Journal on Computer Science and Engineering (IJCSE), Volume 9, Issue 11, Pages 619-622, 2017.
28. Prabhishek Singh, Raj Shree, "Impact of Method Noise on SAR Image Despeckling", International Journal of Information Technology and Web Engineering (IJITWE), Volume 15, Issue 1, Pages 52-63, 2020.
29. Diwakar, Manoj, and Prabhishek Singh. "CT image denoising using multivariate model and its method noise thresholding in non-subsampled shearlet domain." Biomedical Signal Processing and Control 57 (2020): 101754.
30. Prabhishek Singh, Raj Shree, Statistical Modelling of Log Transformed Speckled Image, Vol. 14 No. 8 AUGUST 2016 International Journal of Computer Science and Information Security, (pp. 426-431).