ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

IMPORTANCE OF DWT IN DESPECKLING SAR IMAGES AND EXPERIMENTALLY ANALYZING THE WAVELET BASED THRESHOLDING TECHNIQUES

Prabhishek Singh [*], Dr. Raj Shree
[*] Research Scholar, Department of Information Technology, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India
Assistant Professor, Department of Information Technology, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India

DOI: 10.5281/zenodo.160861

ABSTRACT

Speckle noise is a ‘granular pattern’ special kind of multiplicative noise mainly found in the SAR images and medical images such as CT scan and an ultrasound image. SAR is Synthetic Aperture Radar, special kind of radar that mainly captures the high-resolution images of the broad area of the earth surface. Image despeckling using wavelet transform is one efficient approach as it generates a large number of the small coefficients and a small number of the large coefficients. DWT is applied to analyze the speckled image more efficiently in detail. This paper gives a brief introduction to DWT and experimentally analysed the hard and soft thresholding functions. Matlab Toolbox Main Menu (MATLAB R2014a) is used to realize the practical implementation of thresholding functions and to obtain the experimental results.

KEYWORDS: SAR Image, DWT, Matlab, Hard Thresholding, Soft Thresholding.

INTRODUCTION

Image despeckling is a field of image processing which deals with recovering an original SAR image from a speckled SAR image. Image despeckling can be defined as the process of removing a speckle noise in an image through linear or non-linear filtering techniques.

SAR is the form of Radar that is mounted on the satellites and aircraft that capture the high-resolution images of the broad areas of the earth surface. While capturing such images it has to deal with various weather conditions, day and night, so a special treatment is needed to handle such images because in such case chance of noise intrusion is higher. This granular pattern kind of noise that attacks in such scenario is called as the Speckle noise. SAR images are different from optical images. Since SAR images interact with the ground features in ways different from optical radiation so special treatment is required while interpreting the SAR images. While capturing the broad areas of terrain, SAR has to handle the weather condition, day and night. Unlike optical images, SAR images are formed by the coherent interaction of the transmitted microwave with targets (terrain). This coherent interaction causes random constructive and destructive interference resulting in salt and pepper noise throughout the image.

Prior to DWT based despeckling, FFT-based despeckling techniques were introduced which were unable to preserve the edges of the SAR images which is actually a low pass filtering technique and is not localized in terms of time. This issue was resolved by the wavelet transform as it is localized in terms of space as well as time and also gives better results in terms of edge preservation.

Wavelet denoising using thresholding involves mainly three steps: first is to compute wavelet transform on noisy images, second is to perform thresholding on noisy wavelet coefficients and the last step is applying inverse wavelet transform on the modified wavelet coefficients.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

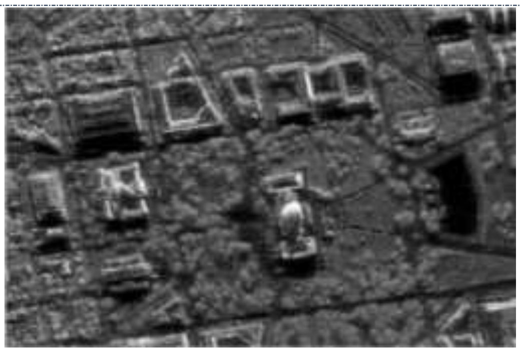

Fig 1. US Capitol and Library of Congress,Washington, D.C.

Fig 2. Noisy Image (Speckle Noise=0.2)(SAR image taken from Sandia National Laboratories.) [1]

In the last two decades, there have been many despeckling techniques developed that eliminate the speckle noise and also preserves and enhances the edge and other features. In the field of radar, adaptive filtering techniques are better denoising techniques including Mean filter [2], Lee filter [3], Frost filter [4], Median filter [5], and Kuan filter [6]. The problem with these standard filtering techniques is that they lose a lot of important features although smoothens the edges and reduces the speckle noise. There are many approaches proposed which are based on the wavelet to reduce the speckle noise in the SAR images. Wavelet provides the best way to separate the noisy part from the original image as the noise persist in the small coefficients and important information exists in the large coefficients and when wavelet thresholding is applied then it eliminate all the small coefficient part. Hence despeckling is performed in much better way.

In this paper, Section II describes the basics of the discrete wavelet transform, Section III describes the wavelet noise thresholding procedure, Section IV shows few experimental results and Conclusion is given in Section VI.

DISCRETE WAVELET TRANSFORM

In image processing application, wavelets are mainly used in image compression and denoising. DWT provides transformation of the image from the spatial domain to the scale frequency domain. MATLAB Wavelet toolbox provides a function named as dwt2 for two-dimensional discrete wavelet transform in order to analyse the amount of high-frequency component present in the image. DWT-2D corresponds to multiresolution approximation expressions. The wavelet basis functions are generated from a single mother wavelet function. DWT is implemented by filter banks is shown in Fig 3.

In 1976 when Croiser, Esteban, and Galand built a technique to decompose the discrete time signals which laid the foundations of DWT. Three other scientists named Crochiere, Weber, and Flanagan did the similar work of coding the speech signals in the same year. Their analysis named the scheme as sub-band coding. In 1983, a technique similar to subband coding was defined by Burt and named that technique as pyramidal coding which is also known as multiresolution analysis.

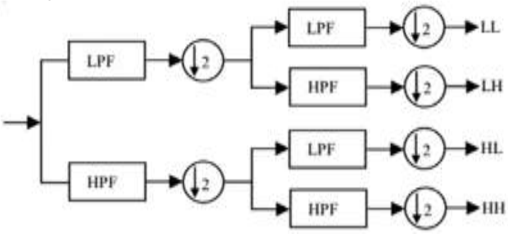

Fig 3. Wavelet Decomposition Using Filter banks [9]

The procedure of DWT on the image is going like this. A high pass filter and low pass filter are selected, in such a way that they exactly half the frequency range between themselves. This filter pair is known as Analysis filter pair. In order to obtain the low-frequency components of the row, the low pass filter is applied for each row. Since low pass filter is a half band filter, output data contains frequencies only in the first half of the original frequency range. Therefore by, Shannon's Sampling Theorem, they can be further subsampled by two, so now the final data contains half the original number of samples. Now for the same row of data, high pass filter is

ISSN: 2277-9655
[Singh* *et al.*, 5(10): October, 2016] Impact Factor: 4.116
IC™ Value: 3.00 CODEN: IJESS7

applied, and the high-frequency components can be separated similarly and placed by the side of low pass components. The method is applied to all rows.

Next step is to perform filtering on each column of the intermediate data. The resulting 2D array of coefficients contains the four bands of data, each labelled as LL, HL, LH and HH. To perform the two level decomposition, the LL band can be further decomposed in the same manner, thereby producing, even more, sub-bands. This decomposition can be done up to any level, thereby resulting in pyramidal decomposition as shown below.

LL (low-low): Noisy Coefficients of Approximation.
LH (low-high): Noisy Coefficients of Vertical Detail.
HL (high-low): Noisy Coefficients of Horizontal Detail.
HH (high-high): Noisy Coefficients of Diagonal Detail.

LL_1	**HL_1**
LH_1	**HH_1**

Fig 4. Single level decomposition

<table>
<tr><td>LL_2</td><td>HL_2</td><td rowspan="2">HL_1</td></tr>
<tr><td>LH_2</td><td>HH_2</td></tr>
<tr><td colspan="2">LH_1</td><td>HH_1</td></tr>
</table>

Fig 5. Two level decomposition

Similar to forward transform to use to separate the image data into various different classes, a reverse transform is used to reassemble the different classes of data into a reconstructed image. A pair of low pass filter and high pass filter is in use here also. Such filter pair is known as Synthesis Filter pair. This filtering procedure is just opposite – we begin from the top level, apply the filter firstly column wise and then row-wise, and similarly proceed to the next level until we reach the first level.

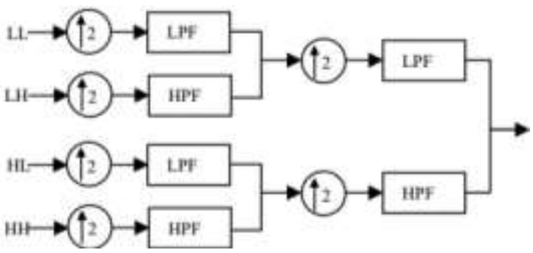

Fig 6. Wavelet Reconstruction Using Filter Banks [9]

WAVELET NOISE THRESHOLDING

The wavelet coefficients calculated by a wavelet transform represent a change in the time series at a particular resolution [13]. To avoid this shortcoming often a nonlinear filtering procedure is used to suppress the noise in the empirical wavelet coefficients [14]. The main idea is based on the fundamental property of the wavelet transform: father and mother functions are well localized in time domain. Therefore one could estimate the

empirical wavelet coefficients independently. To do this let us compare the absolute value of the empirical wavelet coefficient and the standard deviation of the noise [14]. It is clear that if the wavelet coefficient is of the same order of the noise level, then we cannot separate the signal and the noise [14]. In this situation, a good estimator for the wavelet coefficient is zero [14]. In the case when an empirical wavelet coefficient is greater than the noise level a natural estimator for a wavelet coefficient is the empirical wavelet coefficient itself [14]. This idea is called thresholding.
There are mainly three methods: hard thresholding and soft thresholding [13, 14].

A. Compute the wavelet transform and order the wavelet coefficients in increasing frequency.
B. Compute the median absolute deviation (MAD) on the largest wavelet coefficient spectrum.

$$\delta(mad) = \frac{median\{|c_0|, |c_0|, \cdots |c_{2^n-1}{}_{-1}|\}}{0.6745}$$

Here, c0, c1, etc..are the wavelet coefficients.

C. For calculating the noise threshold, 2D-DWT is applied using 'haar' wavelet family and second level of decomposition.
D. Apply a thresholding algorithm to the wavelet coefficients. There are two functions discussed below:
   i. Hard thresholding. Hard thresholding sets any coefficient less than or equal to the threshold to zero [13].

```
if (coef[i] <= thresh)
coef[i] = 0.0;
```

   ii. Soft thresholding. Hard thresholding sets any coefficient less than or equal to the threshold to zero [13]. The threshold is subtracted from any coefficient that is greater than the threshold. This moves the time series toward zero [13].

```
if (coef[i] <= thresh)
coef[i] = 0.0;
else
coef[i] = coef[i] - thresh;
```

EXPERIMENTAL RESULTS

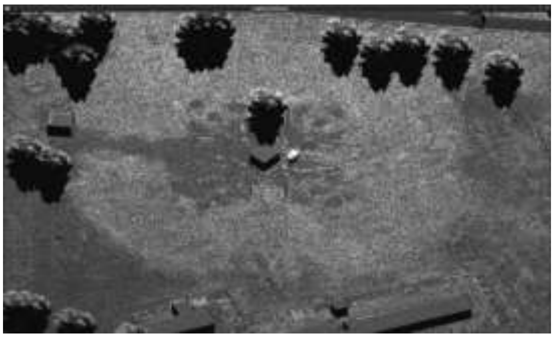

Fig 7. Input Speckled SAR image [12]

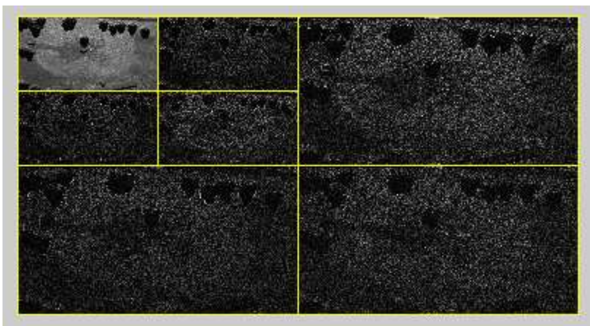

Fig 8. Decomposition at level 2 (2D-DWT)

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

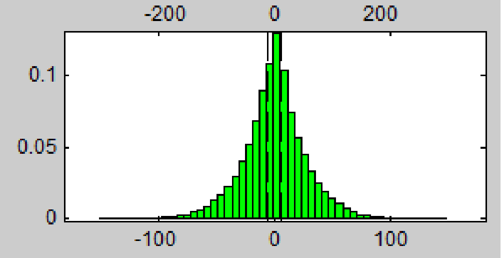

Fig 9. PID of Horizontal details of LL_1

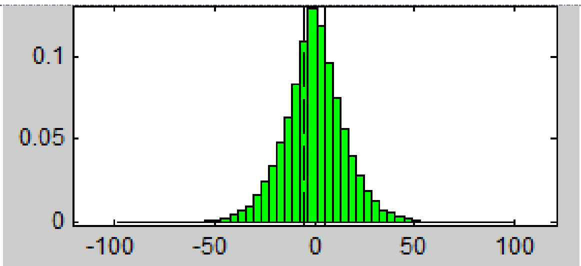

Fig 10. PID of Diagonal details of LL_1

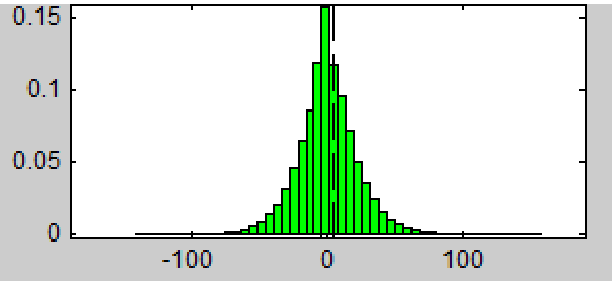

Fig 11. PID of Vertical details of LL_1

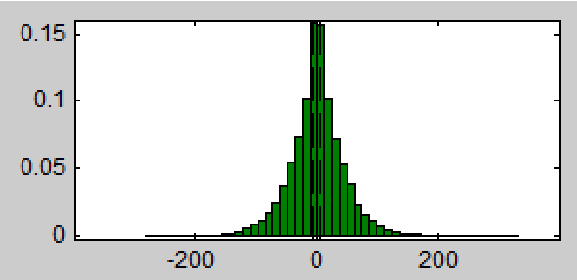

Fig 12. PID of Horizontal details of LL_2

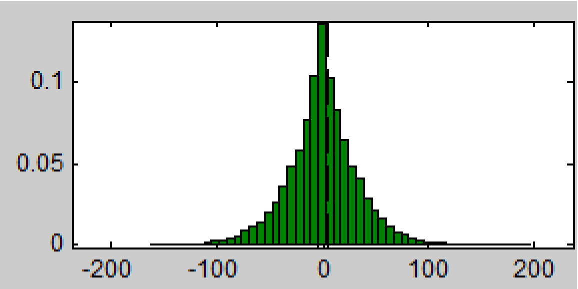

Fig 13. PID of Diagonal details of LL_2

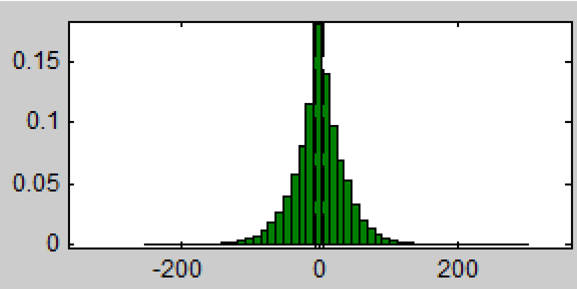

Fig 14. PID of Vertical details of LL_2

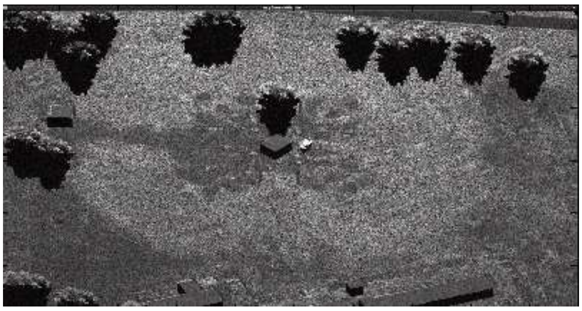

Fig 13. Despeckled Image using Soft Thresholding.

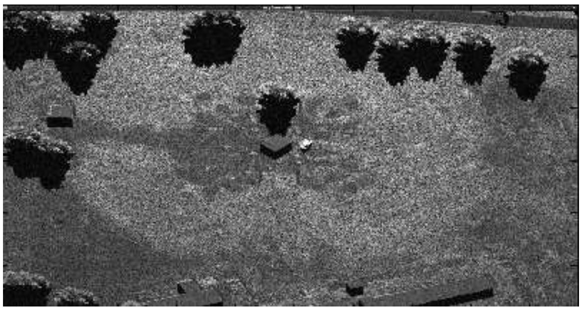

Fig 14. Despeckled Image using Hard Thresholding.

Table 1. Performance Metrics

Type of Noise (Variance)	Thresholding Method	PSNR Value
Speckle(0.04)	Soft	39.7696
Speckle(0.04)	Hard	51.7304

Peak Signal to Noise ratio is calculated by the Matlab inbuilt function named as,

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

peaksnr = psnr(X, org)

with the image org as the reference. X and ref must be of the same size and class.

CONCLUSION

In this paper, the importance and role of the DWT in the field of SAR image despeckling are studied. A major focus is on 2D-DWT. Matlab Toolbox is used to experiment and realize the results of denoising method. Here soft and hard thresholding methods using 'haar' wavelet is used to restore the SAR image. The paper presents the whole procedure by decomposing the speckled image to wavelet coefficients using 2D-DWT and then performing the thresholding methods and finally restoring the speckled image with better performance results. In addition to the study of DWT and denoising of the images, a comparison table is presented to represent the performance metrics which depicts effectiveness of the thresholding methods. It is found that hard thresholding gives better results in the terms of peak signal to noise ratio.

REFERENCES

[1] SAR Image Processing, Sandia National Laboratories (Synthetic Aperture Radar Imagery Database), http://www.sandia.gov/RADAR/imagery/index.html#tab-2
[2] Tinku Acharya and Ajoy K. Ray, "Image Processing Principles and Applications", 2005 edition A John Wiley & Sons, Mc., Publication.
[3] J.S.Lee, "Digital image enhancement and noise filtering by use of local statistics", IEEE Trans. On Pattern Analysis and Matching Intelligence, vol. PAMI-2, pp.165-168, 1980.
[4] V.S.Frost et al, "A model for radar images and its application to adaptive digital filtering of multiplicative noise", IEEE Trans. Pattern Anal. And Machine Intell.,vol. PAMI-4, pp.157-166. 1982.
[5] Anil K.Jain, "Fundamentals of Digital Image Processing" first edition, 1989, Prentice – Hall, Inc.
[6] D.T.Kuan et al., "Adaptive restoration of images with speckle", IEEE Trans. Acc. Speech and signal Proc. Vol. 35, no.3 pp.373-383, March 1987.
[7] Birgir Bjorn Saevarsson,Johannes R.Sveinsson and Jon Atli Benediktsson, "Combined Wavelet and Curvelet Denoising of SAR Images" Proceedings of IEEE 2004.
[8] Guozhong Chen,Xingzhao Liu, "Wavelet-Based Despeckling SAR Images Using Neighbouring Wavelet Coefficients." Proceedings of IEEE 2005.
[9] S.Md.Mansoor Roomi, D.Kalaiyarasi, J.Goma Abhinaya, C.Bhavana, "Edge Preserving SAR image Despeckling",2011 Third National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics.
[10] Abdullah Al Jumah, "Denoising of an Image Using Discrete Stationary Wavelet Transform and Various Thresholding Techniques", Published Online February 2013, Journal of Signal and Information Processing, 2013,4,33-41.
[11] Alka Vishwa, Shilpa Sharma, "Modified Method for Denoising the Ultrasound Images by Wavelet Thresholding", Published Online June 2012 in MECS, I.J. Intelligent Systems and Applications, 2012,6,25-30.
[12] RadarFX - Synthetic Aperture Radar Simulation, **URL:** http://www.mak.com/products/visualize/radarfx-sar-server
[13] Wavelet Noise Thresholding, **URL:** http://www.bearcave.com/misl/misl_tech/wavelets/noise.html
[14] Thresholding, **URL:** http://fedc.wiwi.hu-berlin.de/xplore/tutorials/xlghtmlnode93.html