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SPECKLE NOISE MINIMIZATION IN SAR IMAGES BY USING WAVELET TECHNIQUES

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***Abstract*---Synthetic Aperture Radar (SAR) use microwave radiation to enlighten the earth's surface. In military and civilian field, SAR methods are widely used to acquire high resolution image. Radar pulses are transmitted through synthetic aperture and the reflected signals are combined coherently in SAR technique. Images are intuitively degraded due to the coherent nature of scattering phenomenon called speckle. The most common problem in SAR images is speckle noise. In existing method, Discrete Wavelet Transform (DWT) was used to remove speckle noise. Due to its shift invariant property, despeckling is not obtained properly. In this work, Undecimated Discrete Wavelet Transform (UDWT) is used to solve the speckle noise problem in SAR image. The performance metrics are measured in terms of Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).**

Index Terms— Despeckling, Discrete Wavelet Transform (DWT), Mean Square Error (MSE),Peak Signal to Noise Ratio (PSNR), Undecimated Wavelet Transform (UDWT).

I. INTRODUCTION

Synthetic aperture radar (SAR) is a device used for the purpose of obtaining image of the earth surface. Speckle is a common noise which affects all coherent imaging system. Speckle noise in SAR is more serious, it degrades the image quality of image and causing difficulties for image interpretation.

SAR images models are purely affected by multiplicative noise i.e., simply referred as speckle[1]. Mostly various despeckling methods are used to reduce a noise such a common filters are lee [2], kuan [3], Lee filter is based on the approach that variance over an area, however smoothing is not good for high value of variance and another drawback is that it ignore speckle noise in the area closet to edges and lines. The limitation of kuan filter is that it required equivalent number of looks (ENL) parameter for computation. The median filter required additional computational time for sort the intensity of each set [5]. All the spatial domain filters are depends on kernel window. If the size of the filter window is large, the important details will be lost due to over smoothing. The outcome of the wavelet theory, noising removing in the domain defined by the *discrete wavelet transform* (DWT) may be depends on *thresholding* of DWT feature coordinates of the noisy image, moreover *hard*, or else *soft* [6]. The latter implies that the modulus of the threshold coordinates is reduced by the threshold rate. The noise is consider to be additive in general but speckle noise is multiplicative and it is difficult to remove.For the case of speckle filtering, the logarithm of the noisy image in DWT is either adaptively threshold [7] or empirically shrunk in an adaptive fashion as well [8], has been utilized. The main difficulty is that the storage space of the transformed signal is compact. In DWT, shift invariant transform is used. However this transform is non linear.i.e, the transform of the two signals is not the sum of transform of the individual signals. To overcome this drawback, undecimated discrete wavelet transform that is both linear and shift invariant is used [12].UDWT is redundant, shift invariant and it gives a denser estimate to the continuous wavelet transform than the orthogonal (ON) discrete wavelet transform(DWT).Down sampling is not used in this transform, therefore it has no aliasing problem. In this work, UDWT method is used to remove speckle noise.It gives huge information about the despeckling process and produce better result in reconstruction images. The major concept is that image segmentation can be used at low cost. wavelet coefficients are selected to apply different fast filtering techniques. The computation complexity is reduced significantly and the performance is also increased in terms of PSNR and MSE.

This paper is methodizing as follows. In section II, spatial domain filters are reviewed for despeckling in SAR image, and despeckling of SAR image in DWT domain. In section III, observed image model and the UDWT based solution for SAR image are explained. In section IV, illustrate the performance metric of UDWT. In section V, the experimental result carried out for SAR image analysis which degrades by speckle noise, whereas some conclusion is drawn in section VI.

II. DESPECKLING BASED ON SPATIAL FILTERING AND DWT

In this section, spatial speckle filtering techniques are reviewed,by using the pixel values a mathematical calculation under the kernel is applied. and then central pixel is replaced with the predicted value. The kernel is moved along the image until the entire image covers. After applying the filter a smoothing outcome is encountered.

Lee filter: The Lee filter is the earliest speckle filter in which the variance over an area is low or constant, then smoothing operation will be performed. If the variance is high, smoothing will not be performed. The assumptions of Lee filter is that the speckle noise is an multiplicative.The SAR image can be optimized by a linear model given in (1).

$$Img(i,j) = Im + W * (Cp - Im) \qquad (1)$$

Where Img(i,j) is the hoary degree value of the pixel at indices i and j after filtering. The weighting function W given in (2) and then summed with Im.

$$W = \sigma^2/(\sigma^2 + \rho^2) \qquad (2)$$

Where σ^2 is the pixels values variance contained by the filter window. ρ is the image additive noise variance. The major annoyance of Lee filter is ignoring speckle noise in the areas closest to edges and lines.

Mean Filter: Mean Filtering averages the speckle into the data. This is the least sufficient method of speckle noise decline when it results in defeat of part and resolution. But it preserves application where declaration is not the first concern.

Median Filter: Median filtering is a spatial filtering technique which performs superlative with impulse noise at the same time as retain pointed ends in the image. The Median filter is also removes pulse or spike noises. The major issue of the median filter is its high computational cost.

Kuan Filter: The Kuan filter is considered to be more superior to the Lee filtering. It is not possible to formulate an estimate on the noise variance within the filter window. The Kuan filter simplifies the multiplicative noise into an additive noise as in (3), but ENL is relied from a SAR image to verify a dissimilar weighting function is given in (3) to perform the filtering.

$$W = (1- C_u / C_i)/ (1 + C_u) \qquad (3)$$

The computation of weighting function from the predictable noise deviation coefficient of the image, C_u given in (4)

$$C_u = \sqrt{1 / ENL} \qquad (4)$$

C_i is variation coefficient of the image given in (5).

$$C_i = S/Im \qquad (5)$$

Where standard deviation(s) in filter window and mean intensity (Im) value within the kernel. The only disadvantage of Kuan filter is excess need of computation.

Discrete Wavelet Transform (DWT):
Wavelet is a miniature wave and the length of the window function is confined. Discrete Wavelet Transform (DWT) transforms the data vector into a numerically different vector of the similar range. Data is separated into different frequency Components, each component with resolution matched to its scale. The images are divided into different sub bands based on low pass and high pass filter. Inverse DWT is applied to reconstruct speckle free image. The problems of DWT are lagging in linear and shift invariant property. Wavelet coefficients oscillate with factual and denying values around the irregularities, which complicate their detection and modeling. Wavelet coefficients of the decimated DWT will be changed, if input signal is shifted in time or space. By using non-ideal high and low pass filters with iterative time discrete operations, Wavelet coefficients are estimated. If the wavelet coefficients were not processed, Inverse DWT cancels aliasing. Image details may loss due To limited storage space. Heavy distortions occur because of smoothing. Due to non equal sub bands, image reconstruction is impossible.

III. IMAGE MODELS AND UNDECIMATED WAVELET DOMAIN

For the clarity based purpose, the method assuming the signals are 1-D sequences are described. Extension to the 2-D case is straight forward by using separable processing along rows and columns. Assume that the observed signal is affected by speckle noise and it is expressed as

$$\begin{aligned} y[n] &= x[n].u[n] \\ &= x[n] + x[n].(u[n] - 1) \\ &= x[n] + v[n] \end{aligned} \qquad (6)$$

where $y[n]$ is observed signal and $x[n]$ is speckle free information that would leads to estimate, $u[n]$ is the multiplicative noise and $v[n] = (u[n] - 1)$ is equivalent additive noise model. The multiplicative noise $u[n]$ is assumed as signal independent and $v[n]$ is signal dependent.

Let $w_i^{[j]}$ be undecimated wavelet operator of the considered signal i. it performs the decomposition based on level of decomposition j. the wavelet coefficient of (8) is given by

$$w_y^{[j]}[n] = w_x^{[j]}[n] + w_v^{[j]} \qquad (7)$$

For the simplicity, the above equation is obtained as (10) by eliminating level j and index n.

$$w_y = w_x + w_v \qquad (8)$$

Speckle removing on multi-resolution domain means estimating noise free coefficient and applying inverse UDWT.

IV. PERFORMANCE METRIC OF UDWT

A .Mean Square Error (MSE)
The cumulative square difference between the reconstructed and original image is obtained as MSE. It should be minimum for better performance.

The Mean Square Error can be estimated by

$$MSE = \frac{1}{n}\sum_{i-1}^{n}(\hat{Y}_i - Y_i) \qquad (9)$$

Where Y_i is original value, $\hat{Y}_i$ is estimated value

B. Peak Signal To Noise Ratio (PSNR)

To measure the quality of reconstructed image,PSNR is most commonly used. By the comparison with the reconstructed image, its value should be maximum.

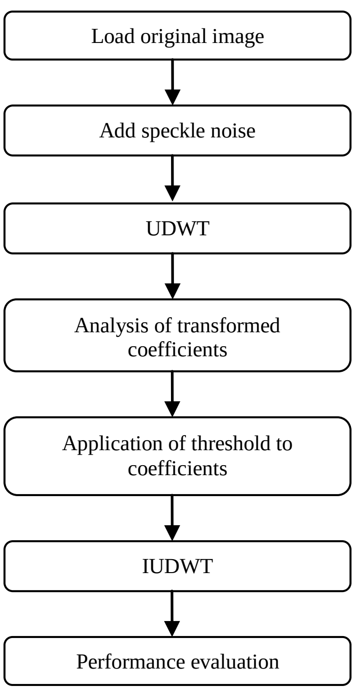
The PSNR is determined by

$$PSNR = 20 * \log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \qquad (10)$$

Where MSE is Mean Square Error.

C. Work flow

Fig 1.Work flow of UDWT



The figure 1 shows the functional procedure of despeckling using UDWT. Here original SAR image is considered and speckle noise is added with different noise variance level from 0.01 to 0.3.In SAR image,Wavelet transform is considered and their Co-efficients are predictable for the transformed SAR image. To reconstruct the transformed image IUDWT is applied and the performance metrics are obtained.

V. EXPERIMENTAL RESULT

In this section, experimental results obtained with algorithm previously described are compared in terms of PSNR and MSE. The result performed by considering 8-bit 256×256 SAR image (Shelter Island, San Diego.) which constitutes speckle noise. The quality of filtered image is measured by $PSNR=10\log_{10}255^2/MSE$. Where MSE is Mean Square Error between original and filtered image.

TABLE I
PSNR value of various filters obtained for SAR image

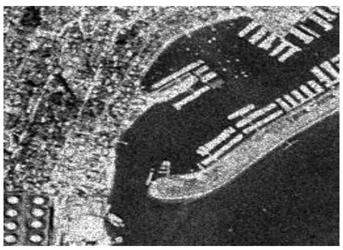
S.NO	ALGORITHMS	PSNR
1	Lee filter	16.37
2	Median filter	18.67
3	Kuan filter	19.03
4	Mean filter	19.45
5	DWT	20.09
6	UDWT	22.50

Table I shows the performance of various spatial filters such as Lee filter, Median filter, Mean filter and Kuan filter with DWT and UDWT filter. Among the spatial filter Mean filter gives maximum PSNR value. UDWT is better than all the above filters. The table II shows the MSE value of various filters obtained for SAR image. The Values are obtained for the speckle variance of 0.08.

TABLE II
MSE value of various filters obtained for SAR image.

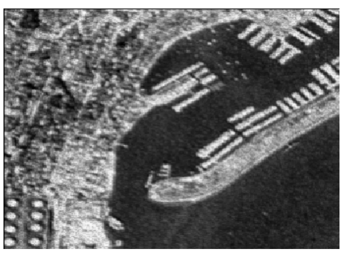
S.NO	ALGORITHMS	MSE
1	Lee filter	1498
2	Median filter	883
3	Kuan filter	785
4	Mean filter	738
5	DWT	636
6	UDWT	365

(a) Original SAR image

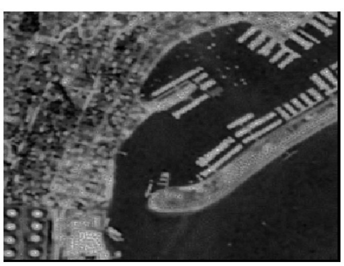


(b) SAR image with speckle noise

Fig: 1.1 SAR image of Shelter Island, San Diego

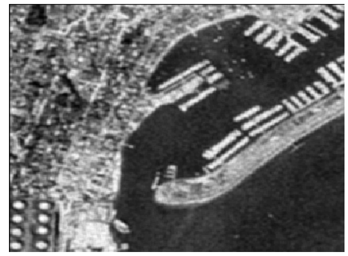


(a) Kuan filter



(b) Lee filter

(c) Median filter



(d) Mean filter

(e) DWT

(f) UDWT

Fig: 1.2 Despeckled image using various approaches.

The fig: 1.1 shows a) 8-bit 256×256 SAR image of Shelter Island, San Diego .b) the affected by the speckle noise. Fig: 1.2 shows various despeckling version such as a) kuan filter, b) lee filter c) mean filter,d) median filer e)DWT and f)UDWT. If the speckle noise in increases, the performance of mean filter is reduced.

PSNR Plot

The figure 1.3 shows the PSNR value of UDWT is increases when compared to other standard speckle filters and it also shows mean filter gives better result than lee, kuan and median filter and DWT.

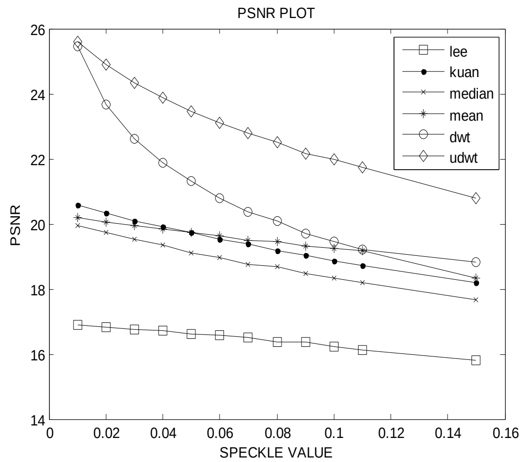


Fig 1.3 PSNR plot of UDWT

MSE Plot

The figure 1.4 shows the MSE value of UDWT is decreases when compared to other standard speckle filters and it also shows mean filter gives better result than lee, Kuan and median filter and DWT.

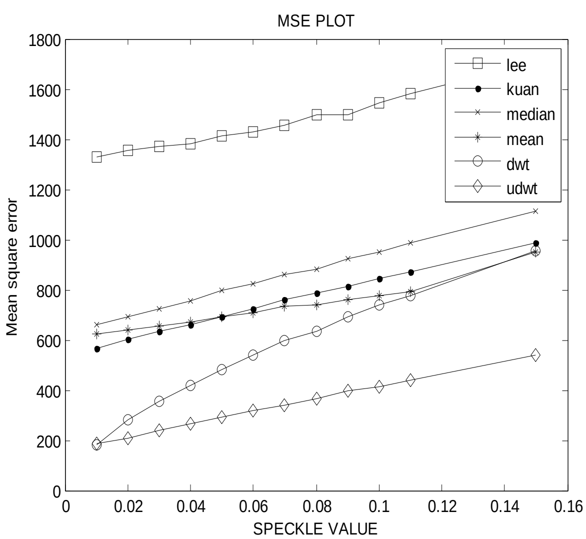


Fig 1.4 MSE plot of UDWT

VI. CONCLUSION

Speckle noise reduction in SAR image has been demonstrated successfully by Undecimated Discrete Wavelet Transform (UDWT). Among the spatial speckle filters, mean filter gives maximum PSNR value. Wavelet transform gives better result in terms of PSNR compared to spatial speckle filter, UDWT approach in SAR images yields maximum PSNR for each noise variance. However for high resolution SAR image needs high computational burden. In future, a new modeling of the statistics of wavelet coefficients will reduce the computational complexity.

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