SPECKLE NOISE REDUCTION OF SYNTHETIC APERTURE RADAR (SAR) IMAGE USING MULTI-RESOLUTION TECHNIQUE

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ABSTRACT
Synthetic Aperture Radar (SAR) images are contaminated by multiplicative speckle noise, a chaotic phenomenon that results from coherent energy imaging; and that obscures the scene complex and strongly reduces the possibility to observe objects. Multiplicative speckle noise limits the classical coder/decoder algorithm in spatial domain. Various scalar wavelet based techniques so far developed for removal various noise but; these wavelet transforms cannot posses all desirable features simultaneously. Relatively new class of wavelets called Multiwavelet; are new addition to the body of wavelet theory. Realizable as matrix –valued filter banks leading to wavelet basis, were introduced and which are able to posses all desirable properties simultaneously and overcomes the limitations of scalar wavelets. In this paper, we proposed a de-noising scheme of speckle noise removal within the Multiwavelet framework. Newly proposed method achieves favorable PSNR and performs superior speckle noise reduction.

KEY WORDS
Synthetic Aperture Radar (SAR), Multiplicative Speckle Noise, Multi-resolution technique

1. Introduction
Synthetic aperture radar (SAR) is a remote sensing technology that uses the motion of the radar transmitter to synthesize an antenna aperture much larger than the actual antenna aperture in order to yield high spatial resolution radar images. In the last few years, high-quality images of the earth produced by SAR systems, carried on a variety of airborne and space borne platforms, have become increasingly available. A major problem with use of SAR imagery is a kind of signal dependent noise: the speckle noise i.e. consequences image formation under coherent radiation [1, 2, 3]. Since speckle damages radiometric resolution and affects human interpretation and scene analysis. It is generally desirable that image brightness is to be uniform except where it changes to form an image. There is a variation in the brightness of a displayed image even when no image detail is present. This variation is usually random and has no particular pattern reducing the image quality specifically when the images are small and have relatively low contrast. This random variation in image brightness is nothing but a noise. All SAR images contain multiplicative speckle noise [4-6]. The presence of noise gives an image a grainy, textured, or snowy appearance. No imaging method is free of noise.

Many authors have developed SAR image de-noising methods mostly focus on using wavelet transform for its multiresolution decomposition allowing efficient image analysis and noise reduction. Recent developed Multiwavelet can posses’s compact support, orthogonality, symmetric, and high order vanish moments simultaneously which desirable properties for best performance in image are de-noising while scalar wavelet lack of it. Thus Multiwavelet offers the possibility of superior performance in obviating some of the limitations of scalar wavelets [7-8]. In this work we explore an algorithm using soft thresholding speckle noise reduction with various decomposition and reconstruction filters with different pre-processing filters.

2. Multi-resolution Technique:

Wavelet (Multi-resolution analysis) is a useful transform tool for signal processing applications such as image compression and de-noising. Wavelets are generated by one scaling function, so called scalar wavelets too. In comparison to scalar wavelets, Multiwavelet have several advantages such as short support, orthogonality, symmetry, and vanishing moments.[9-11]

Multiwavelet can simultaneously provide perfect reconstruction while preserving length (orthogonality), good performance at the boundaries (via linear-phase symmetry) and a high order of approximation (vanishing moments).

Multiwavelets are characterized with several scaling functions and associated wavelet functions. Let the scaling functions be denoted in vector form as Φ(t) = [Φ1(t), Φ2(t), . . . , Φr(t)]T, where Φ(t) is called the multiscaling function, T denotes the vector transpose and Φj(t) is the jth scaling function. Likewise, let the wavelets be denoted as Ψ(t) = [ψ1(t), ψ2(t), . . . , ψr(t)] T, where ψj(t) is the jth wavelet function. Then, the dilation and wavelet equations for Multiwavelet take the following forms, respectively:

$$\phi(t) = \sum_{k} H_k \phi(2t - k),$$

$$\psi(t) = \sum_{k} G_k \phi(2t - k)$$

(1)
Multiwavelet bases of multiplicity r provide a multi-resolution analysis is $\{V_n\}_{n \in \mathbb{Z}}$ of $L^2(\mathbb{R})$ using the Multiwavelet function $\Psi(t)$ and multiscaling function $\Phi(t)$.

The jth scaling space is given by

$$V_j = \text{span}\{2^{j/2} \phi_i(2^j \cdot t - k) : 1 \leq i \leq r, k \in \mathbb{Z}\}$$

The jth wavelet space is given by

$$W_j = \text{span}\{2^{j/2} \psi_i(2^j \cdot t - k) : 1 \leq i \leq r, k \in \mathbb{Z}\}$$

Where $V_j \perp W_j$. The multiscaling function satisfied the above r-scale equation (1). Where $H_k$ and $G_k$ are $r \times r$ matrix coefficients of low pass multifilters and high pass multifilters. The low pass filters $H$ and the high pass filter $G$ is $r \times r$ matrix filters, instead of scalars. In theory, $r$ could be as large as possible, but in practice it is usually chosen to be two i.e $r=2$ [12-16].

The Multiwavelet used here have two channels, so there will be two sets of scaling coefficients and two sets of wavelet coefficients. Thus the two-dimensional image data after one level Multiwavelet decomposition are replaced by sixteen blocks corresponding to the subbands as shown in Fig.1 (a). The sixteen blocks represent either low pass or high pass filtering in each direction, not four blocks in scalar wavelet decomposition. For two-level Multiwavelet decomposition, the four low frequency subbands are decomposed into sixteen blocks again as shown in Fig.1(a) and (b).

Figure 1: (a) Illustration of one-level Multiwavelet decomposition.

3. Multiwavelet based Image De-noising

Synthetic Aperture Radar images are usually corrupted by speckle noise. There are various techniques available for de-noising the signal and images. Wavelet thresholding is an effective method of de-noising noisy signals; which plays an important role in de-noising the image and it is treated as widely investigated noise reduction method [17-20]. The wavelet de-noising is achieved via thresholding or shrinkage. Wavelet thresholding procedure removes noise by thresholding only the wavelet coefficient of the details coefficients, by keeping the low-resolution coefficients unaltered. There are two thresholding methods frequently used soft thresholding and hard thresholding. A procedure of keep or kill is called hard thresholding and alternative to this procedure is called soft thresholding. The soft thresholding is normally chosen over the hard thresholding because it yields more visually enhanced images than hard thresholding because the latter is discontinuous and yields abrupt artifacts in the recovered images, especially when the noise energy is significant. The dynamic range of synthetic aperture radar (SAR) images is higher by a factor of 5 compared to other passive remote sensing images in visible and infrared regions. More over, the speckle noise which is inherent to synthetic aperture imaging systems blurs its high frequency textural and structural information of content [20-21]. The statistical approaches for speckle suppression are found to suppress the speckle noise at the signal. The most dominant information of single frequency and single polarization SAR image are manifest in the form of local spatial variations of tone as textural and structural details [22-24]. An attempt has been made in this study to use wavelet transform for local image enhancement using a speckle filtered SAR image [24-25]. Most wavelet-based speckle noise removal approaches apply the soft-thresholding proposed by Donoho, through introducing a suitable threshold to suppress noise [3]. But during the filtering process, edge information is also smoothed unfavorable to further image processing. By modification, this noise reduction method can keep edge and texture information at the meantime of speckle suppression.

3.2 Procedure for De-noising

The general procedure for de-noising through soft thresholding includes the following three steps.

a) Multiwavelet Decomposition

b) Threshold detail coefficients (i.e. Diagonal, Horizontal and Vertical)

c) Reconstruct.

In the above three steps, firstly the image is decomposed by the wavelet transform, secondly the detail coefficients are thresholded by the soft thresholding algorithm. After the thresholding the new detail coefficients are obtained. Using these new coefficients the image is reconstructed, which is the denoised image by wavelet transform [3], [4], [7], [8].

4. Experimental Analysis and Interpretation.

In this experimental work we have done experiments on SAR image for removal of speckle noise using various multi-resolution techniques. We have considered ‘haar’, ‘d4’, ‘la8’, ‘bi9’, ‘bi7’, ‘ghm’, ‘cl’, ‘bih52s’, ‘sa4’ and ‘cardbal2’ as a decomposition and reconstruction filters with different preprocessing filters i.e. ‘bih5ap’, ‘ghmap’ and ‘sadap’ by keeping SNR=35; this will not affect perceptual visual quality of the image. The result
are evaluated by an error visibility quality metrics MSE and PSNR at level 1 to Level 5 of decomposition for all the above decomposition and reconstruction filters with ‘bih5ap’ preprocessing filters at level 1 gives us good results out of that at level 1 ‘haar’ gives promising results. We have also analyzed all the above filters from level 1 to level 5 of decomposition. Performance is good except ‘bih52s’ filter.

We have also analyzed all the above filters with different preprocessing filter i.e. ‘ghmap’ and ‘sa4ap’. The same trend of the results we are getting even by changing preprocessing filters i.e. at first level all filters give us a good result. The same evaluation criterion is followed ‘haar’ at level 2 gives a promising result with a ‘ghmp’ and ‘sa4ap’ preprocessing filters. Among ‘haar’, ‘d4’, ‘la8’, ‘bi9’, ‘bi7’, ‘ghm’, ‘el’, ‘bih52s’, ‘sa4’ and ‘cardbal2’ Haar gives the good results at level 2 with ‘bih5ap’ preprocessing filter. If we increase the order and level of the wavelet filters; which leads to computational complexity and deterioration of visual quality of the de-noised image and the results are shown in table-1 and figure-1.

5. Conclusion

De-noising of SAR images through Multiwavelet techniques in image processing method has noticeable advantage over DWT. In this paper we have applied ‘haar’, ‘d4’, ‘la8’, ‘bi9’, ‘bi7’, ‘ghm’, ‘el’, ‘bih52s’, ‘sa4’ and ‘cardbal2’ on SAR images at level 1 to 5 with different pre-processing filters. We have focused how the MSE and PSNR vary by selecting appropriate decomposition, reconstruction and pre-processing filters. It is observed that ‘haar’ gives the good results at level 1 and level 2 with ‘bih5ap’ preprocessing filter. If we increase the level of decomposition the computational complexity will increase. So, it is concluded that the removal of noise is depends on the type of image and type of transforms because, there is no filter that performs the best for all images. Hence, there is always necessary to select the appropriate threshold value to get perceived quality of the image with less distortion.

References:


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DF: Decomposition Filter, RF: Reconstruction Filters, PF: Pre-processing Filters, DL: Decomposition Level.

Table-1: Shows the MSE and PSNR with varying level of decomposition

Figure1- Shows the MSE and PSNR at different level of decomposition