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DE-SPECKLING OF SAR IMAGES BASED ON OPTIMAL BASIS WAVELET VIA PATCH ORDERING

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ABSTRACT
Synthetic Aperture Radar (SAR) technology has mainly used for capturing high quality images from higher altitudes. SAR imagery has become an important application over optical satellite imagery because of its ability to operate in any whether condition. The SAR image acquired via coherent imaging are associated with a noise called speckle noise, which is multiplicative in nature. The presence of speckle noise degrades the quality of SAR image then leads to loss of crucial information. So it has become very important to remove the speckle noise from SAR images using suitable techniques. Many different SAR image-despeckling techniques proposed over past few years. In this paper, proposed a new idea for de-speckling the SAR image to the maximum and the proposed method achieves state-of-the-art de-speckling performance.

INTRODUCTION
The Synthetic Aperture Radar (SAR) used to capture high-resolution images from higher altitudes. SAR is capable of operating under any climatic changes like day and night, sunny and cloudy, has become more and more popular in our daily lives and in military tasks. SAR system takes the advantage of complex information processing capability of modern digital electronics and long-range propagation characteristics of radar signals to provide high quality imagery. There are many applications of SAR in different areas like in Geology, Ecology, Hydrology, Oceanography, Surface surveillance, Mine detection and automatic target recognition [2]. Whereas unfortunately SAR images acquired via coherent imaging are associated with a noise-like phenomenon called, ground clutter or speckle noise.

The presence of speckle will affect the performance in various applications of SAR image processing. For example, it decreases correct classification rate in terrain classification [6] and increases the false alarm rate in target/edge detection [12].

To solve this problem, the multiplicative model converted into additive model by taking the logarithm of the noisy image. Then, the image de-noising methods like wavelet shrinkage, total variation, sparse representation etc. and it can applied to the logarithmic SAR image. Another way is to write the multiplicative noise in an additive but signal dependent way.

Many classical de-speckling techniques use this model and perform filtering in the spatial domain based on Minimum Mean Square Error (MMSE) criterion or Maximum A Posteriori (MAP) criterion. Some advanced methods also adopt the additive signal dependent model, but operate in the wavelet domain or no subsampled shearlet transform domain. An example of SAR image shown in Fig 1.

SPECKLE NOISE MODEL
Noise model should observed for all kinds of noise before preprocessing, for the easy application of noise removal algorithm. Speckle is not an exact noise but is more of granular pattern. Generally, there are two basic modes of noise. One is additive and the other is multiplicative. The additive noise is systematic, easily modeled and can be removed easily with lesser efforts. But multiplicative noise is caused by de-phased echoes from scatters is image dependent and complex to model. Multiplicative noise is difficult to reduce although it contains useful

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information. The speckle noise in SAR image is associated with multiplicative noise with unit mean and variance. A multiplicative speckle noise represented by:

f (x, y) =s (x, y). n (x, y) (1)

Apply logarithmic operator to both sides of equation, and obtained the following equation.

ln (Y)=ln(S)=ln(N) (2)

This equation can written as,

y (x, y) =s (x, y) +e (x, y) (3)

Here y (x, y), s (x, y) and e (x, y) represent logarithmically transformed noisy data, signal and speckle noise respectively. Now this nonlinear transform changes the statistics of speckle noise. The pixels of log-transformed images are mutually independent makes extraction of information easier.

Figure 1.SAR image

LITURATURE SURVEY

There are various papers, which explain about different types of filtering methods for SAR image de-speckling. In this section of literature survey, we get to know the information about speckle noise. Multi look processing and adaptive image restoration techniques are the two SAR de-speckling techniques used by widely. In [9], multi look processing is the technique, which averages several independent images or number of looks (L). The SAR image, which processed using digital image processing in frequency domain mostly by wavelet, transform but in spatial domain, it has done by manipulating the neighborhood pixels.

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Multi look integration technique has a drawback, there is an increase in computation when number of looks (L) is increased and degradation of image resolution happens with smoothing of uniform areas. Adaptive image restoration on the other hand uses post image formation technique, which makes use of filters like Lee filter, point wise linear filters Maximum A Posteriori (MAP filter and Local statistics filters.

In [8], Non-Local Means is a new method for de-noising. It has based on non-local averaging of all pixels in the image. Local averaging filters like anisotropic filtering, Gaussian smooth filtering, total variation minimization approach and neighborhood filtering exhibit their own limitations. Gaussian has a problem that it is optimal in flat parts of the image but the texture and edges are blurred. The anisotropic filter and total variation minimization approach are preserving edges while flat and textured regions are degraded. The drawback of neighborhood filtering is that it compares only gray level values in a single pixel, which is not advisable. The alternative to this local approach is NL – means, which is, not only compares grey level in a single point but also whole neighborhood and performs well than local method in terms of method noise, visual quality and MSE.

In [3], propose a synthetic aperture radar (SAR) image de-speckling method based on patch ordering and transform-domain filtering. The multiplicative noise model transformed into the additive model by applying logarithmic transformation with bias correction to the original SAR image. Then, a two-stage filtering strategy has adopted.

The first stage is coarse filtering, which can suppress speckle effectively. In this stage, patches are extracted, ordered and filtered using SSC. Then apply inverse permutation and sub image averaging. The second stage is refined filtering. The small artifacts generated by coarse filtering is eliminate in this stage. Same procedure can used here but uses 2D wavelet hard thresholding instead of SSC.

Merits and demerits

Every de-noising methods has lots of advantages and disadvantages. Some de-noised methods and its merits and demerits are discuss in Table 1 and Table 2.

Table 1. Merits of various SAR image de-noising method

De-noising method	**Merits**
Multi-look integration technique	L looks average used to reduce speckle noise
Adaptive image restoration technique	Residual speckle is processed using post image formation filters like Lee, MAP etc. adaptive to the local texture information, smooths speckle in homogenous areas and processing texture and high frequency information in heterogeneous areas.
Non Local Mean	Set of similar patches used to suppress the noise and the similarity is based on Euclidean distance between two the patches.
Patch-ordering based de-speckling	Achieves state-of-the-art de-speckling performance in terms of PSNR, SSIM index, equivalent number of looks ENLs, and ratio image.

Table 2. Demerits of various SAR image de-noising methods

De-noising method	**Demerits**
Multi-look integration technique	Increase in computational complexity if number of looks increases and thus degrading image resolution.
Adaptive image restoration technique	Blurring and degradation in image resolution if size of window increases
Non Local Mean	Computational burden due to its complexity of calculating the weight of the pixel / voxel
Patch-ordering based de-speckling	Uses 2D wavelet hard thresholding, which is an oldest method.

PROPOSED WORK

Here proposes a synthetic aperture radar (SAR) image de-speckling method. Firstly, the multiplicative noise model has converted into the additive model by applying Logarithmic transformation with bias correction to the original SAR image. Then, a two-stage filtering strategy has adopted. First stage is coarse filtering which can used to suppress speckle effectively. In this stage, we have to extract the sliding patches from the logarithmic SAR image, after that order them in a smooth way by applying simplified patch ordering algorithm especially for SAR images. The ordered patches have filtered by learned simultaneous sparse coding (SSC). SSC is a recent technology and is one of the best image filtering methods more over it has very strong noise reduction ability.

Then, the coarse filtering result reconstructed from the filtered patches using inverse permutation and sub image averaging. The flowchart for coarse filtering has given in the Fig 2. Main actions performed in coarse filtering are application of logarithmic transformation, extraction of sliding patches, ordering by simplified patch ordering algorithm, filtering by SSC, inverse permutation and sub-image averaging.

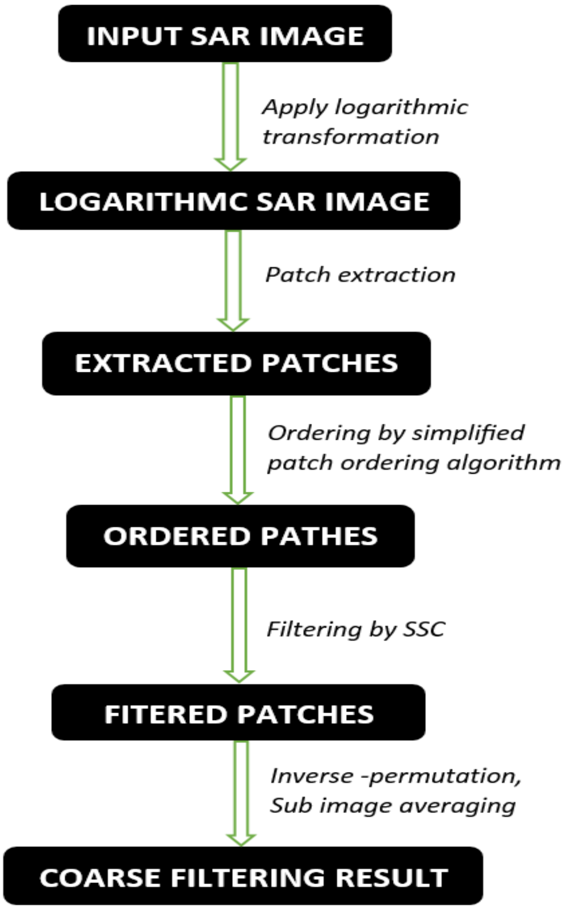


Figure 2. Coarse filtering framework.

The second stage is refined filtering. Here a new adaptive thresholding function has introduced to improve the de-noising efficiency. An Optimum Wavelet Basis (OWB) have employed for input image decomposition [1]. The OWB packet selects because of its dynamic decomposition nature in forming the sub bands. Based on analyzing the statistical parameters of each sub band coefficient, the threshold value has picked up. Bayesian maximum a posteriori (MAP) estimate has used to obtain the thresholding function, which is necessary in the enhancement and/or elimination of the wavelet coefficients. Then, the optimal linear interpolation between the mean value of the corresponding sub band and each coefficient used to calculate the modified version of dominant coefficients.

ALGORITHM

We propose a new SAR image de-speckling algorithm in this paper. The algorithm consists of two stages. In the first stage, the log-intensity SAR image is filtered by patch ordering and SSC. Although de-noising via SSC can suppress speckle effectively, it produces small artifacts, which caused by the learned dictionary [11]. Thus, the first stage is a coarse filtering stage. The artifacts generated by sparse representation can alleviated by other transform domain methods. To handle this, we adopt a refined filtering stage. The complete procedure for first stage has summarized in the Algorithm 1.

Algorithm 1: Coarse filtering

Input: The input SAR image I, the ENL E.

Step 1: Apply a 3×3 Boxcar filter into input SAR image I, and obtain the boxcar filtering result I_B.

Step 2: Apply logarithmic transformation with bias correction to I for calculating the log-intensity image $I^{(ln)}$.

Step 3: Extract sliding patches G_B and G_1 of size $\sqrt{n1} \times \sqrt{n1}$ from I_B and $I^{(ln)}$, respectively.

Step 4: Order the patches G_B by simplified patch ordering algorithm, and obtain the set Ω_1. Then calculate the ordered patches H_1 by $H_1 = G_1 Z \Omega_1$.

Step 5: De-noise H_1 by SSC, and obtain the filtering result $\hat{H}_1$. Then perform inverse permutation on $\hat{H}_1$, i.e. $\hat{G}_1 = \hat{H}_1 Z^{-1} \Omega_1$.

Step 6: Reconstruct the filtering result $\hat{I}_1^{(ln)}$ from $\hat{G}$ by sub-image averaging.

Step 7: Calculate the coarse filtering result x_1 by applying exponential transformation to $\hat{I}_1^{(ln)}$.

Output: Course filtering result.

To improve the de-noising efficiency OWB has employed. It is a top-down search method for selecting optimal basis. To Find an optimal threshold value is not an easy task. Here we have to estimate the image noise variance. The noise is additive, then the observation model can be written as below.

$$Y^s_{i,j} = X^s_{i,j} + \eta^s_{i,j} \quad (4)$$

where $Y^s_{i,j}$ is the noise coefficients of sub band S, $X^s_{i,j}$ is the coefficients of the clean sub-band, and $\eta^s_{i,j}$ is noise coefficients. The noise and coefficients of the clean image are independent, So

$$\sigma^2_{Y,s} = \sigma^2_{X,s} + \sigma^2_\eta \quad (5)$$

where $\sigma^2_{Y,s}$ is the variance of coefficients ($Y_{i,j}$) in sub band S. From this, the value of σ2 X,s can be derived as

$$\sigma^2_{X,s} = \max(\sigma^2_{Y,s} - \sigma^2_\eta, 0) \quad (6)$$

The obtained value of threshold λs is infinite when the value of $\sigma^2_{X,s}$ is zero. The complete procedure has given in Algorithm 2.

Algorithm 2: De-noising with OWB

Step 1: Perform WP decomposition to obtain OWB of a noisy image up to four levels (L = 4) by using Shannon entropy.

Step 2: Calculate the noise variance using (4).

Step 3: For each sub band S in level d, estimate the threshold value and statistical parameters:

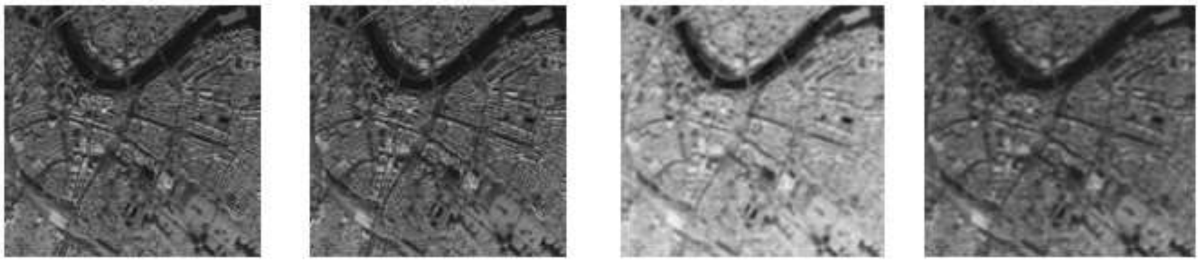
a) variance of sub band (σ2 Y, s);
b) mean of sub band(μs);
c) estimate the variance of clean image using (6);
d) term αd,s using ;
e) term β ;
f) Threshold value.

Step 4: Threshold all sub-band's coefficients using the proposed thresholding technique.

Step 5: Perform the inverse WPT to reconstruct the de-noised image.

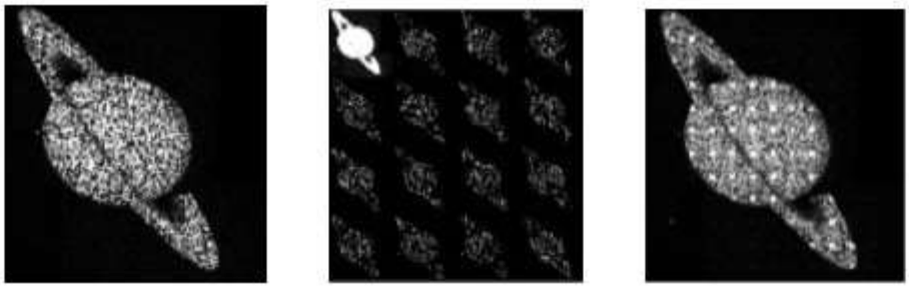
EXPERIMENTAL RESULT

In this paper, both simulated images and real SAR images used to test the filtering performance of the proposed technique. The proposed method has compared with three state-of-the-art de-speckling methods such as, MIDAL [4], SAR-BM3D [7] and PPB [5] and we compare the proposed method with the homomorphic version of the original patch ordering method (H-PO) [10]. Fig 3 shows coarse filtering result with very good PSNR value and Fig 4 shows the experimental result using OWB.



(a) (b) (c) (d)

Figure 3. (a) input SAR image, (b) noisy image, (c) sub image averaging, (d) coarse filtering result with PSNR =30.2731 dB



(a) (b) (c)

Figure 4. (a) noisy image, (b) OWB, (c) de-noised image.

CONCLUSION

This paper proposes a novel framework for reducing speckle noise in SAR images. First, we apply homomorphic transformation and speckle filtering has implemented in the logarithmic domain. Then coarse filtering and OWB de-noising performed to get the noise free SAR image. The proposed method has strong speckle reduction ability and computational cost is modest. So it is suitable for many image processing applications, such as display systems, noisy texture analyzing systems, digital multimedia broadcasting and medical image analyzing systems.

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