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Bivariate Cauchy Prior based method using Interscale Dependence

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Abstract: In this project work, the speckle noise from SAR images is removed using a despeckling algorithm that accounts for the intrascale dependencies of the DTCWT sub bands. The Dual Tree Complex Wavelet Transform with Maximum A Posteriori estimator gives better denoising performance compared to the conventional despeckling methods. The performance can be improved by using Adaptive Dual Tree Complex Wavelet Transform with Maximum A Posteriori estimator considering both inter and intrascale dependencies across the wavelet coefficients. The performance is analyzed interms of ENL, MSE and PSNR. Experimental results have shown that the proposed method gives better denoising performance compared to the conventional methods.

Keywords: Speckle Removal, ENL, MSE, PSNR, Denoising

I. Introduction

Synthetic aperture radar provides the capability for all-weather, autonomous navigation and guidance. By forming SAR reflectivity images of the terrain and then "correlating" the SAR image with a stored reference (obtained from optical photography or a previous SAR image), a navigation update can be obtained. Position accuracies of less than a SAR resolution cell can be obtained. SAR may also be used to guidance applications by pointing or "squinting" the antenna beam in the direction of motion of the airborne platform. SAR imaging offers the capability for penetrating materials which are optically opaque, and thus not visible by optical or IR techniques. Low-frequency SARs may be used under certain conditions to penetrate foliage and even soil. This provides the capability for imaging targets normally hidden by trees, brush, and other ground cover. To obtain adequate foliage and soil penetration, SARs must operate at relatively low frequencies (10 MHz to 1 GHz). Recent studies have shown that SAR may provide a limited capability for imaging selected underground targets, such as utility lines, arms caches, bunkers, mines, etc. Depth of penetration varies with soil conditions (moisture content, conductivity, etc.) and target size, but individual measurements have shown the capability for detecting 55-gallon drums and power lines at depths of several meters. In dry sand, penetration depths of 10's of meters are possible.

The Nonlinear Multiscale Wavelet Diffusion algorithm[1] for speckle suppression is designed to utilize the favourable denoising properties like the scarcity and multiresolution properties of the wavelet and the iterative edge enhancement feature of nonlinear diffusion. This technique removes the signal mean during the edge estimation, and the edge related components can be easily separated from the noise related components by magnitude difference. Results of the tests of this method on both synthetic and real ultrasonic images reveals that the nonlinear multiscale wavelet diffusion significantly reduce speckle in both high and low contrast edges.

In the wavelet domain noise filtration technique [2], a single parameter can be used to balance the preservation of (expert-dependent) relevant details against the degree of noise reduction. The algorithm exploits generally valid knowledge about the correlation of significant image features across the resolution scales to perform a preliminary coefficient classification. This preliminary coefficient classification is used to empirically estimate the statistical distributions of the coefficients that represent useful image features on the one hand and mainly noise on the other. The adaptation to the spatial context in the image is achieved by using a wavelet domain indicator of the local spatial activity. The results demonstrate its usefulness for noise suppression in medical ultrasound and magnetic resonance imaging.

An Enhanced Directional Smoothing (EDS) Algorithm [3] for Edge-Preserving Smoothing of Synthetic-Aperture Radar Images is proposed. Most of the filters described in the literature are based on the fact that ratio of the standard deviation to the signal value, the "coefficient of variation," is theoretically constant at every point in a SAR image. However this fact is irrelevant for directional and enhanced directional smoothening. The EDS filter has a speckle reduction approach that performs spatial filtering in a square-moving window know as kernel, window size is selected to be odd. The EDS filtering is based on the statistical relationship between the central pixel and its surround-ding pixels. To protect the edges from blurring while smoothing, a directional averaging filter is used by the author. EDS performs the filtering based on either local statistical data given in the filter window to determine the noise variance within the filter window, or estimating the local noise variance using the effective equivalent number of looks (ENL) of a SAR image.

Speckle deduction in ultrasound [4] images by minimization of total variation is done here. To limit the noise in an image, some techniques are based on the calculation of an average intensity in each pixel of the image by considering some neighborhood. However, these techniques tend to attenuate contours present in the image. This affect edge and particularly penalizing for the segmentation algorithms whose finality is to find contours. The restoration method by minimization of total variation consists in minimizing under constraints of the great variations present in the image while preserving contours. An ultrasound image restoration method based on the resolution of non linear partial derivative equation (PDE) is presented in this work. Results of the work show that speckle is practically removed by this method, discontinuities are practically preserved, and the regions of the restored image are more homogeneous and improve the result of segmentation.

II. PROPOSED FRAMEWORK

A. *Spatially Adaptive Wavelet based Maximum A Posteriori Estimation*

In Spatially Adaptive wavelet based Maximum A Posteriori (SAMAP), the MAP estimators are developed by employing a Cauchy PDF as a prior for modelling the coefficients of the log-transformed reflectance. The spatial dependency of the wavelet coefficients is incorporated with the Bayesian estimation process significantly enhance the denoising process. The method is summarized as follows,

Carry out the log-transformation of the SAR image. Apply three level Discrete Wavelet Transform (DWT) on the log-transformed image and obtain an approximation, horizontal (LH), vertical (HL) and diagonal (HH) subbands.

Estimate the parameters σ_n and γ

a. The standard deviation σ_n of the log transformed noise is obtained by

$$\sigma_n = \frac{\mathrm{mad}(d(p,m))}{0.6745}, \quad d(p,m) \in \text{HH subband} \qquad (1)$$

Γ can be obtained as

$$\gamma = (m - \sigma_n^{2})^{1/2} \qquad (2)$$

where m be the first order central moment of the noisy wavelet coefficients,

$$m = \frac{1}{N} \sum_{i=1}^{N} d((p,m)^{i}) \qquad (3)$$

b. Perform the inverse wavelet transform of the coefficients obtained in step iv.

c. Perform the exponential transformation of the values obtained in step v to obtain the denoised image.

B. *Bivariate Cauchy Maximum A Posteriori Estimation*

In this method, a dual tree complex wavelet transform based despeckling algorithm is used for synthetic aperture radar images, considering the significant dependencies of the wavelet coefficients across different scales. The wavelet coefficients in each scale is modelled with a bivariate Cauchy probability density function. The method is summarized as follows.

i. Carry out the log-transformation of the SAR image.

ii. Apply three level Dual Tree Complex Wavelet Transform (DTCWT) on the log-transformed image and obtain two approximations, six directional subbands strongly oriented at angles of $\pm 15^0$, $\pm 45^0$, $\pm 75^0$.The six directional details are high frequency components, thus denoising has to be done only in the directional subbands.

a. The standard deviation σ_n of the log transformed noise is obtained by

$$\sigma_n = \frac{\mathrm{mad}(d(p,m))}{0.6745}, \quad d(p,m) \in \text{HH subband} \qquad (4)$$

b. γ can be obtained as

$$\gamma=\sqrt{\left[m-\frac{\sigma_n^2}{4\pi}\right]\frac{\Gamma\left(\frac{3}{2}\right)}{\Gamma\left(\frac{-1}{2}\right)}8\pi} \quad (5)$$

where m be the first order central moment of the noisy wavelet coefficients,

$$m=\frac{1}{N}\sum_{i=1}^{N} d((p,m)^{i}) \quad (6)$$

iii. Obtain the estimates using MAP estimator
iv. Perform the inverse Dual Tree Complex Wavelet Transform of the coefficients obtained in step iv.
v. Perform the exponential transformation of the values obtained in step v to obtain the despeckled image.

III. RESULTS OF PROPOSED WORK

The performance of the proposed work based on despeckling using Bivariate Cauchy Prior based method using Interscale Dependence which utilizes Maximum A Posteriori considering interscale and intrascale dependencies(for three level decomposition) is compared with Lee filter, gamma MAP filter, Spatially Adaptive Wavelet Based MAP(SAMAP) estimation and Bivariate Cauchy Maximum A Posteriori(BCMAP) estimation. The Proposed framework achieves better results than all other methods.The experimental results for the real time SAR image of pentagon is shown below.


(a)


(b)


(c)


(d)


(e)


(f)

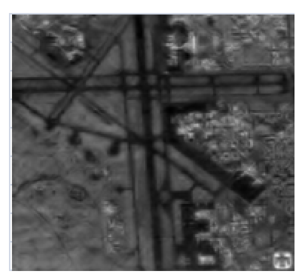
Figure.1. Results obtained with different despeckling filters for the real time pentagon image. (a) Original SAR image (b) Lee filter (c) Gamma MAP filter (d) SAMAP filter (e) BCMAP filter (f) Proposed work

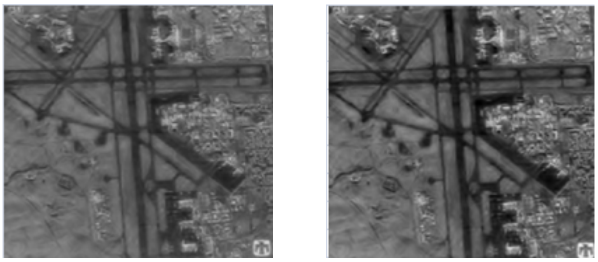
The experimental results for the real time SAR image of an airport is shown below.


(a)


(b)


(c)


(d)



(e) (f)

Figure.2.Results obtained with different despeckling filters for the real time airport image. (a) Original SAR image (b) Lee filter (c) Gamma MAP filter (d) SAMAP filter (e) BCMAP filter (f) Proposed work

The performance of the proposed work based on Dual tree complex wavelet transform with MAP estimator by considering interscale and intrascale dependencies is analyzed using the images obtained from TerraSAR-X satellite and the Sandia Twin Otter aircraft. Since the noise free images are not available in real time SAR image, two uniform areas namely regions1 and 2 have been selected in each SAR image for performance analysis. The selected region compose of 49x56 and 32x 69 pixels for vegetation. In this proposed work, three level decomposition is performed for despeckling the SAR image. The ENL performance is given by

TABLE I
ENL VALUES OBTAINED WITH SPECKLE FILTERS APPLIED TO REAL TIME VEGETATION IMAGE

Method	ENL Region1(49x56)	ENL Region2(32x69)
Before Despeckling	3.79	3.59
Lee filter	11.04	10.64
MAP filter	22.87	19.08
SAMAP filter	31.83	27.95
BCMAP filter	35.89	31.82
Proposed Work	46.21	40.42

IV. CONCLUSION

In this project work, the speckle noise from SAR images is removed using a despeckling algorithm that accounts for the intrascale dependencies of the DTCWT sub bands. The Dual Tree Complex Wavelet Transform with Maximum A Posteriori estimator gives better denoising performance compared to the conventional despeckling methods. The performance can be improved by using Adaptive Dual Tree Complex Wavelet Transform with Maximum A Posteriori estimator considering both inter and intrascale dependencies across the wavelet coefficients. The performance is analyzed interms of ENL, MSE and PSNR. Experimental results have shown that the proposed method gives better denoising performance compared to the conventional methods.

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