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Synthetic Aperture Radar (SAR) Image Processing using Hybrid Enhanced Lee Filter with Discrete Wavelet Transform

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Abstract - *Synthetic Aperture Radar (SAR) images are significant application of optical satellite images due to its ability to work in any weather situations. This has applications in ecology, geology, agriculture, hydrology, oceanography and military so on. With enhancement of SAR technology, resolution of images has increased. These images are corrupted by a strong noise, known as Speckle noise. This noise reduces overall quality of image. So it is necessary to erase speckle noise and preserve all features in SAR images with suitable strategy. In this paper, we proposed a new hybrid technique that combines Wavelet based demonizing and anisotropic diffusion filter, both these techniques provides better filtering capability and enhances edges. By applying these techniques the efficiency of system is increased and noise is reduced to the greater extent. To Remove the Speckle Noise efficiently a New hybrid technique is developed using Wavelet based anisotropic filter which works efficiently and removes the full removal of Speckle and preserve the edges up to greater extent. The Results are evaluated in terms of statistical parameters and compared with existing algorithm. The performance is evaluated in terms of COC, ENL and PSNR, the proposed hybrid approach provide fully demonized images when compared with existing model.*

INTRODUCTION

For remote sensing, Synthetic Aperture Radar (SAR) is a very powerful and attractive tool because of its high spatial resolution. Yet, automatic interpretation of *SAR* images is very difficult [1] because of speckle noise. Speckle affects all coherent imaging systems and can be regarded as multiplicative noise. Some standard speckle filters, e.g. [2], yield easily computable equations but do not preserve fine details in complex images. A recently proposed technique [1] achieves high performance utilizing Bayes estimation and random fields as texture models; however, its computational complexity is high. In order to achieve both high quality demonized images and a fast computation wavelet transform [3] is an attractive choice. Currently, there is a great activity in area of context-based and locally adaptive wavelet shrinkage [4].

Noise in Synthetic Apertures Radar (SAR) Images

Synthetic Apertures Radar (SAR) technique is popular due to its usability under different weather conditions, its ability to penetrate through clouds and soil [5]. A SAR image is a mean intensity estimate of radar reflectivity of region which is being imaged. Speckle noise in such system is to be referred as difference among a measurement and true mean value. Degraded image with speckle noise in ultrasound imaging is given by equation;

$$d\,(U,V) = I(U,V) * S(U,V)$$

Where, d (U,V)is the degraded ultrasound image with speckle, I(U,V)is the original image and S(U,V) is speckle noise. Where (U,V)denotes pixel location. The multiplicative nature of speckle complicates noise reduction procedure [5].

Major causes of speckle noise

This is because of incorrect assumption that ultrasound pulse always travel in a straight line to and fro from reflecting interference. Another source of reverberations is that a small portion of the returning sound pulse may be reflected back into the tissues by the transducer surface itself, and generates a new echo at twice the depth. Speckle is the result of the diffuse scattering, which occurs when an ultrasound pulse randomly interferes with the small particles or objects on a scale comparable to the sound wavelength. The backscattered echoes from irresolvable random tissue in homogeneities in ultrasound imaging and from objects in Radar imaging undergo constructive and destructive interferences resulting in mottled b-scan image [6].

Need for filtering

Speckle [7] degrades quality of US and SAR images and thereby reducing ability of a human observer to discriminate fine details of diagnostic examination. Images with speckle noise will results in reducing contrast of image and difficult to perform image processing operations like edge detection, segmentation.

Discrete Wavelet Transform

Wavelet transform has gained widespread acceptance in signal processing and image compression. Recently JPEG committee has released its new image coding standard, JPEG-2000, which has been based upon DWT. Wavelet transform, decomposes a signal into a set of basic functions. These basis functions are known as wavelets. Wavelets are obtained from one prototype wavelet known as mother wavelet by dilations and shifting [8]. DWT has been introduced as a highly efficient and flexible technique for sub band decomposition of signals. 2DDWT is nowadays established as a key operation in image processing. It is multi-resolution analysis and it decomposes images into wavelet coefficients and scaling function.

In Discrete Wavelet Transform, signal energy concentrates to specific wavelet coefficients. This characteristic is useful for compressing images [9]. Wavelets convert image into a series of wavelets that can be stored more efficiently than pixel blocks. Wavelets have rough edges; they are able to render pictures better by eliminating the ―blackness. In DWT, a timescale representation of digital signal is obtained utilizing digital filtering techniques. Signal to be analyzed is passed through filters with different cut-off frequencies at distinct scales. It is simple to implement and minimize computation time and resources required [9]. A 2-D DWT can be seen as a 1-D wavelet scheme which transform along the rows and then a 1-D wavelet transform along columns. 2-D DWT operates in a straight forward manner by inserting array transposition between the two 1-D DWT. The rows of array are processed first with only one level of decomposition. This essentially divides the array into two vertical halves, with the first half storing the average coefficients, while the second vertical half stores the detail coefficients. This process is repeated again with the columns, resulting in four sub-bands within the array defined by filter output.

IMAGE PREPROCESSING

M. Mansourpour , M.A. Rajabi , J.A.R. Blais proposed the Frost Filter technique for image preprocessing. The Frost filter replaces the pixel of interest with a weighted sum of the values within the nxn moving kernel. The weighting factors decrease with distance from the pixel of interest. The weighting factors increase for the central pixels as variance within the kernel increases. This filter assumes multiplicative noise and stationary noise statistics [10].

1. A gradient based adaptive median filter

It is used for removal of speckle noises in SAR images. In this method fourth order gradient is introduced to reduce the oscillations at high frequencies (i.e. noise) which are much effective than second order gradients. This method is used to reduce/remove the speckle noise, preserves information, edges and spatial resolution and it was proposed by S.Manikandan, ,Chhabi Nigam, J P Vardhani and A.Vengadarajan [11].

2. The Wavelet Coefficient Shrinkage (WCS) filter

It is based on the use of Symmetric Daubechies (SD) wavelets. There are two advantages in using SD wavelets (ie) symmetric extension prevents discontinuities introduced by a periodic wrapping of the data and identical vanishing of the second centered moment of the real part of the scaling function provides better approximation at sampling points [12]. The WCS filter developer by L. Gagnon and A. Jouan in 1997.

3. Discrete Wavelet Transform (DWT)

It has been employed in order to preserve the high-frequency components of the image. The resolution enhancement technique uses DWT to decompose the input image into different sub bands. Then, the high-frequency sub band images and the input low-resolution image have been interpolated, followed by combining all these images to generate a new resolution enhanced image by using inverse DWT [13]. In order to achieve a sharper image, an intermediate stage for estimating the high-frequency sub bands has been proposed by P. Karunakar, V. Praveen and O. Ravi Kumar.

LITERATURE SURVEY

M. Kim, et al., [14] In general, game theory is a framework for optimizing the multi-objective and multidisciplinary problems. It substitutes the notion of optimum, irrelevant when more than one criteria is under consideration with the introduction of equilibrium. There are many definitions of game equilibria, depending on the nature of the game and the most known is the Nash equilibrium, classically accepted as solution to static with complete information games. Game theory was originally used in economic field for a long time, let's just mentioned the application of distributed control system by the partial differential equation is a novel field. Game theory is very suitable for processing against standards.

Skolnik, et al., [15] Discovered the overview of Radar has long been used for military and non-military purposes in a wide variety of applications such as imaging, guidance, remote sensing and global positioning. Development of radar as a tool for ship and aircraft detection was started during 1920s. In 1922, the first continuous wave radar system was demonstrated by Taylor. The first pulse radar system was developed in 1934 with operating frequency 60MHz by Naval Research Laboratory (NRL), US. At the same time, radar systems for tracking and detection of aircraft were developed both in Great Britain and Germany during the early 1930s.

Raman Maini and Himanshu Aggarwal [16] 2009 in their paper *"Performance evaluation of various speckle noise reduction filters on Medical images*" proposed and compares five different speckle reduction filters quantitatively using simulated imageries. The results have been presented by filtered images, statistical tables and diagrams. Filtering is one of the common methods which are used to reduce the speckle noises. Finally, the best filter has been recommended based on the statistical and experimental results in terms of PSNR.

Bibo Lu [17] 2010 in their paper " *SAR Speckle Reduction Based on Nonlocal Means Method"* proposed a novel SAR speckle reduction method base on nonlocal means (NLM) filter. NLM is applied to remove additive noise after taking the logarithm of the original speckle noise. The proposed method can preserve edges and protect more fine details. Results on real speckle SAR images are given and have also compared our method with some related methods.

Udomhunskal and Wongsita[18] 2010 in their paper "*Ultrasonic speckle denoising using the combination of wavelet transform and Wiener filter "*proposed a method for Ultrasonic speckle denoising using the combination of wavelet transform and wiener filter to reduce the speckle noise while preserving the resolvable details. In this method, the first step is to apply the 2D discrete wavelet transform of the noisy image. Then, the wiener filter is applied over areas in each detail subband (HH, HL and LH.From the experimental results, found that this method gives better results for removal of ultrasonic speckle denoising.

AsaduzzamanBabu and Mahmoud R. El-Sakka [19] in their paper "*A Hybrid Scaling Factor for Speckle Reducing Anisotropic Diffusion"*proposed a hybrid scaling factor that reduces edge dislocation and preserves the sharpness of edges. The proposed technique is based on ratio-based edge detection for an estimation of the homogeneity of the initially selected region.

Gregorio Andria [20]in their paper "*A Suitable Threshold for Speckle Reduction in Ultrasound Images"* proposed a Thresholding technique for removal of speckle noise in ultrasound (US) medical images. The method comprises the use of an adaptive data-driven exponential operator that operates on wavelet coefficients of the US image to suppress undesired effects of disturbances, preserving signal details. The results show that the proposed denoising method increases the medical image quality. And, therefore, it can be a useful tool in medical diagnosis.

Jyothishaj.Nair [21] in4 their paper "*Speckle Noise Reduction Using Fourth Order Complex Diffusion Based Homomorphic Filter*" proposed a method of fourth order complex diffusion technique to perform Homomorphic filtering for speckle noise reduction. Both quantitative and qualitative evaluation is carried out for different noise variances and found that the proposed approach out performs the existing methods in terms of root means square error (RMSE) value and peak signal to noise ratio (PSNR).

PROPOSED TECHNIQUE

In this paper the basic idea is the estimation of the uncorrupted image from the noisy image or distorted image is known as "image denoising". From Noisy distortions there are various methods to help restore an image. Choosing the best method plays a very important role for getting the desired image. In my thesis report a study is made on "Speckle Noise reduction using anisotropic filter based on Wavelets" there are various existing techniques to remove the Speckle Noise Reduction but due to some drawbacks these techniques cannot remove Speckle Noise efficiently. The major drawbacks of the existing filters are:

- The adaptive filters that are lee filter, Kuan filter, and Frost filter are not able to perform a full removal of Speckle without losing any edges because they rely on local statistical data and this Statistical data related to the filtered pixel value and this data depends upon the filter window over an area.

- As these existing filters are very much sensitive to the Window Shape and Window Size. If the Window Shape is very much larger than over smoothing will occurs. As window size is smaller than the Smoothing Capability of the Window will decrease.

So to overcome these limitations we proposed a new hybrid technique that combines Wavelet based denoising and anisotropic diffusion filter. As Wavelet is Frame based Approach. As it is independent on both Space and Time, wavelet provides better Resolution. In Anisotropic diffusion filter it is based on partial differential equation. As it does not depends upon the window size. It is based on Mean Square Error approach. So it provides better filtering capability and enhances the edges. By applying these techniques the efficiency of the system is increased and noise is reduced to the greater extent.

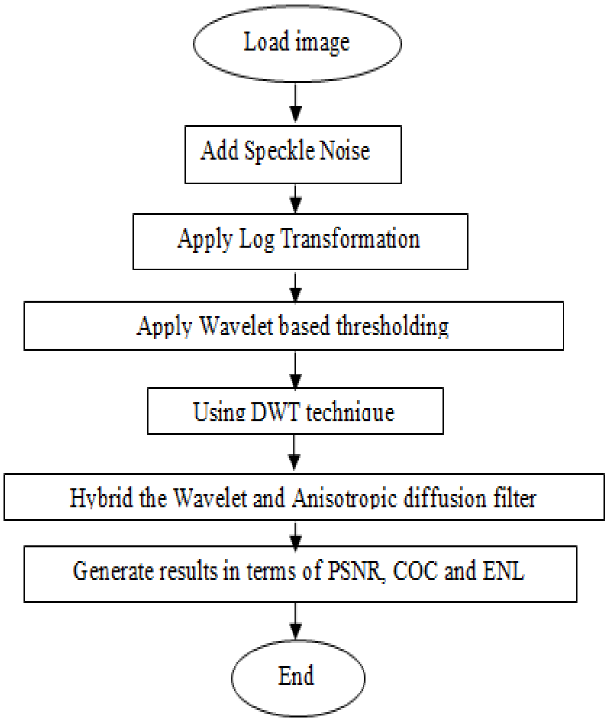

Figure 2 shows the Methodology of Speckle Noise Reduction using Anisotropic filter based on Wavelets

RESULTS AND DISCUSSION

Implementation Snapshots:

4.1 Synthetic Lena images were taken

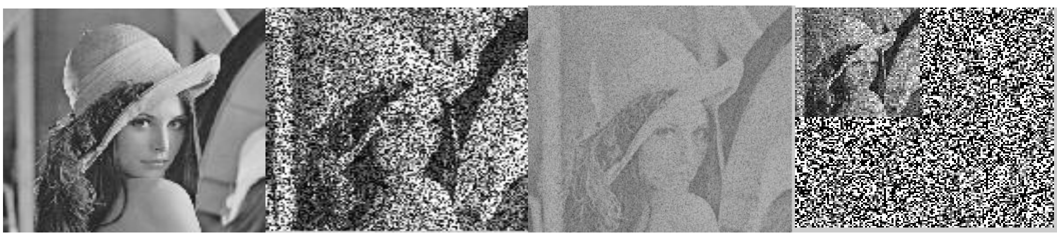

Fig 4.1 (a)Original image, Fig 4.1 (b) Noisy Image, Fig 4.1 (c) Log transformation, Fig 4.1 (d) Wavelet Decomposition

Fig 4.1 (e) proposed Hybrid Anisotropic diffusion filter

In fig 4.1(a) load the image by using the command imread. Syntax of image read function is I=imread (filename, fmt)
Definition: Imread reads a gray scale image from the file specified by the string filename, the string fmt specifies the format of the file. I is the matrix of each element of the pixel with the corresponding gray scale of the image then input image is converted into double.

In fig 4.1(b) add Speckle Noise by using the command imnoise. l = imnoise (I,' speckle', v) in this I is the intensity value of the pixels and v is the variance of the noise. In this image the variance is taken as 0.04.

In fig 4.1 (c) Apply Log Transformation to make the noise additive uses of Log transform

It is used to expand the dark value of the pixels in images and compressed the values of the pixels.
With the large variations in the pixel values it compresses the dynamic range of the images.

In fig 4.1 (d) Apply 2D level Wavelet Transform

In this approximation image is used to smooth out the image. Using the DWT technique and applying the Bayesian wavelet thresholding is used. In wavelet thresholding only detailed sub bands contains noise but it is not true. Since approximation subband also contains the noise. So our aim is to smooth the approximation image. It consists of four bands. Upper left band is known as LL band which is known as approximation image.

In fig 4.1 (e) Hybrid Anisotropic filter with Wavelet denoising

In this hybrid Anisotropic filter is used which provides better edge preservation and smooth the edges. As Anisotropic filter is based on partial differential equation approach. It provides better results than other existing algorithms.

4.2 Barbara image were taken

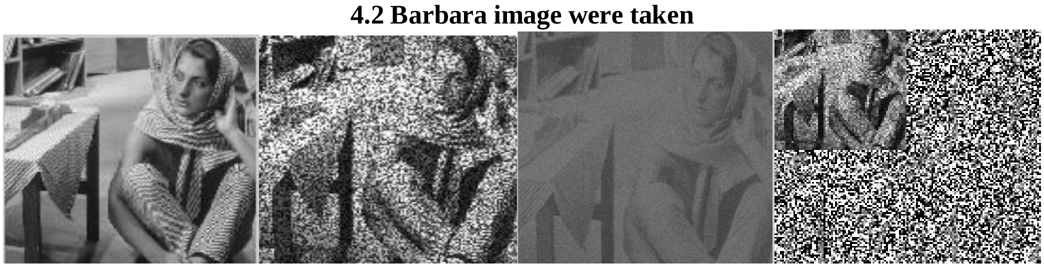

Fig 4.2(a) Original Image, Fig 4.2 (b) Noisy Image, Fig 4.2 (c) Log Transformation, Fig 4.2 (d) Wavelet Decomposition

Fig 4.2 (e) proposed Hybrid Anisotropic filter

In fig 4.2(a) load the image by using the command imread. Syntax of image read function is I=imread (filename, fmt)
Definition: Imread reads a gray scale image from the file specified by the string filename, the string fmt specifies the format of the file. It is the matrix of each element of the pixel with the corresponding grey scale of the image. Then input image is converted into double.

In fig 4.1 (c) Apply Log Transformation to make the noise additive uses of Log transform

It is used to expand the dark value of the pixels in images and compressed the values of the pixels.
With the large variations in the pixel values it compresses the dynamic range of the images.

In fig 4.2(b) add Speckle Noise by using the command imnoise. l = imnoise (I,' speckle', v) in this I is the intensity value of the pixels and v is the variance of the noise. In this image the variance is taken as 0.04.

In fig 4.2 (d) Apply 2D level Wavelet Transform

In this approximation image is used to smooth out the image. Using the DWT technique and applying the Bayesian wavelet thresholding is used. In wavelet thresholding only detailed sub bands contains noise but it is not true. Since approximation subband also contains the noise. So our aim is to smooth the approximation image. It consists of four bands. Upper left band is known as LL band which is known as approximation image.

In fig 4.2 (e) Hybrid Anisotropic filter with Wavelet denoising

In this hybrid Anisotropic filter is used which provides better edge preservation and smooth the edges. As Anisotropic filter is based on partial differential equation approach. It provides better results than other existing algorithms.

4.3 Hyderabad image were taken

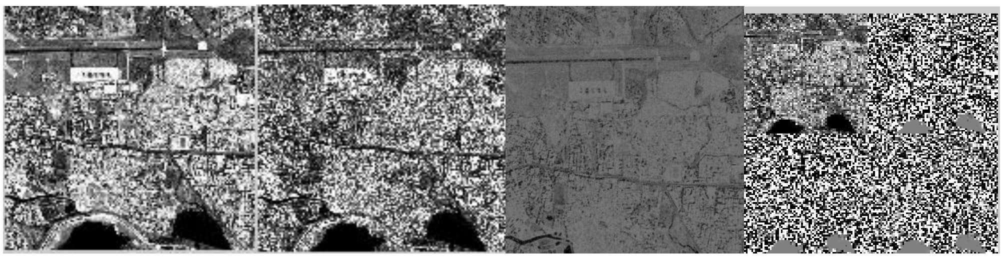

Fig 4.3 (a) Original Image, Fig 4.3 (b) Noisy Image, Fig 4.3 (c) Log transformation, Fig 4.3 (d) Wavelet Decomposition

Fig 4.3 (e) proposed Hybrid Anisotropic filter

In fig 4.3(a) load the image by using the command imread. Syntax of image read function is I=imread (filename, fmt) Definition: Imread reads a gray scale image from the file specified by the string filename, the string fmt specifies the format of the file. It is the matrix of each element of the pixel with the corresponding grey scale of the image. Then input image is converted into double.

In fig 4.3 (c) Apply Log Transformation to make the noise additive uses of Log transform

It is used to expand the dark value of the pixels in images and compressed the values of the pixels.

With the large variations in the pixel values it compresses the dynamic range of the images.

In fig 4.3(b) add Speckle Noise by using the command imnoise. l = imnoise (I,' speckle', v) in this I is the intensity value of the pixels and v is the variance of the noise. In this image the variance is taken as 0.04.

In fig 4.3 (d) Apply 2D level Wavelet Transform

In this approximation image is used to smooth out the image. Using the DWT technique and applying the Bayesian wavelet thresholding is used. In wavelet thresholding only detailed sub bands contains noise but it is not true. Since approximation subband also contains the noise. So our aim is to smooth the approximation image. It consists of four bands. Upper left band is known as LL band which is known as approximation image.

In fig 4.3 (e) Hybrid Anisotropic filter with Wavelet denoising

In this hybrid Anisotropic filter is used which provides better edge preservation and smooth the edges. As Anisotropic filter is based on partial differential equation approach. It provides better results than other existing algorithms.

Two tests are carried out ,one is to find out the PSNR, ENL and COC values of different images which will be passed through the proposed filter and then a comparison is carried out for these values with that of an existing filter, here we take LEE filter for the comparison.

Table 1: Values of PSNR,ENL and COC for prediction model

[1] **Cover Image**	[2] **PSNR(db)**	[3] **ENL**	[4] **COC**
[5] **Lena.png**	[6] **29.25**	[7] **58.7045**	[8] **0.1029**
[9] **Barbara.png** [10]	[11] **27.25**	[12] **27.7646**	[13] **0.1086**
[14] **Hyderabad.png** [15]	[16] **26.45**	[17] **9.2939**	[18] **0.0226**

Table1 shows the distortions present in these images which are calculated by PSNR (peak signal to noise ratio), ENL (Equivalent No of Looks) and COC (coefficient of correlation).

Table 2: Comparison of Existing Techniques (LEE filter)

[19] **Comparison**	[20] **Algorithm**	[21] **PSNR**	[22] **ENL**	[23] **COC**
[24] **Existing technique**	[25] **DWT and Lee Filter**	[26] **25.21**	[27] **55.3935**	[28] **0.2672**
[29] **Proposed technique**	[30] **DWT using reverse biorthogonal and** [31] **Anisotropic filter**	[32] **29.25**	[33] **58.7045**	[34] **0.1029**

Table 2 shows the comapison of one of the existing techinques i. e., the Lee filter on one of the images. Results show a marked increase in PSNR and ENL values and a decrease inn COC values of the image which were the main goal of thedespeckling filter.

VI CONCLUSION

The proposed tool will help in improving the errors which were not worked in previous models. The results show that the previous filters could not provide fully denoised images as their COC, ENL and PSNR values were quite low when compared to the proposed model. This model will be independent of the window size, thus avoiding over smoothing of the image which was a major drawback in the previous models. So, we have tried to change from an old approach of window based filtering to a more efficient frame based approach along with the Anisotropic diffusion filter, based on Mean Square Error approach. The basic concept of creating a hybrid filter is to improve the overall results of both the filters which otherwise can have a few back draws if compared independently.

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