Synthetic Aperture Radar (SAR) ImagesProcessing: A Review

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Abstract - The Synthetic Aperture Radar (SAR) images are important application of optical satellite images because of its ability to operate in any weather conditions. This has applications in agriculture, geology, ecology, hydrology, oceanography and military, etc. With the improvement of SAR technology, the resolution of the images has increased. These images are corrupted by a strong noise, called Speckle noise. This noise degrades the overall quality of the image. So it is important to remove the speckle noise and preserve all features in SAR images with the suitable technique. This paper presents the various important techniques which are used to remove speckle noise from SAR images and each technique has their own advantages and limitations. After the study of different techniques we will choose suitable technique for despeckling.

***Key Words*: Synthetic Aperture Radar images, Speckle noise, Denoising, Filters, Wavelet Transform**

1.INTRODUCTION

The Synthetic Aperture Radar (SAR) is convenient for giving information about earth's surface by using the respective motion between antenna and its target [1]. In various applications like automatic target detection, surface surveillance, mine detection etc. the SAR images provide very important information. In SAR imagery, one of the main problems is that the image textures are usually contaminated with multiplicative speckle noise which is due to coherent radiation in the process of imaging [2]. The texture present in the images usually contains important information about the scene. The objective of despeckling method is to remove speckle noise and to protect all textural features in the SAR images [3].

Speckle Noise: Speckle noise is a multiplicative noise usually found in photos, mainly in Synthetic Aperture Radar (SAR) and medical imaging [3]. It causes the grey level of a local area. Various techniques are proposed to reduce multiplicative noise. Hybrid filters are proposed for speckle noise reduction [4]. Filters used to reduce the speckle noise are Lee, Kuan [3] and Frost filters. These filters are used to reduce speckle noise. They are not capable to remove full speckle noise without losing any edges because they based on local statistical data related to the filtered pixel. This data develop on the occurrence of the filter window area. There are various methods to reduce the speckle noise using adaptive and non-adaptive filters. Adaptive filters are useful to adapt the weightings across the image to the speckle level but the non-adaptive filters are useful to adapt weightings uniformly across the entire image.

1.1 Estimation of similarities and dissimilarities between different filters:

1) **Lee Filter:** Lee filters are used to specked (smooth noisy) data have intensity related to the noisy image scene and it also have an additive and multiplicative component. Lee filtering is standard deviation based (sigma) filter. In this filter data 9based on statistics which is calculated within particular filter windows. Unlike a typical low pass smoothing filter, lee filter and other similar sigma filter used to prevent image sharpness and detail while suppressing noise [7]. The pixel being filtered is replaced by the value calculated using the surrounding pixels. Lee filter is based on multiplicative speckle model and it is used to preserve the details of local statistics [5] [11]. It works on the variance basis. It performs smoothing operation if variance of the area is low but not for high variance. It can preserve details in low as well as in high contrast because it has adaptive nature.

2) **Enhanced Lee Filter:** Enhanced Lee filters are used to reduce the speckle noise in radar images while simultaneously preserve texture information. This filter is adapted from lee filter. It uses local statics (coefficient of variance) within individual filter windows. In this each pixel is divided into three classes, which are treated as following:-
   - **Homogeneous:** Pixel value is repeated by the average of filter window.
   - **Heterogeneous:** Pixel value is repeated by a weighted approximation.
   - **Point target:** The pixel value is not changed.

3) **Frost Filter:** Frost filter is used to reduce speckle noise while preserving the edges in radar images [7]. The frost filter is a damped circularly symmetric filter and it uses local statistics. The pixel which is filtered then converted by the value calculated based on the distance from the filter center, the local variance and the damping factor [5] [11]. For filtering process it uses a negative exponential distribution for the cause of image denoising i.e. speckle noise and local image statistics. This performs a weighted average of the cell values in the filter window, with the weights for each cell to minimize the mean square error of the signal.

4) **Enhanced Frost Filter:** Enhanced Frost filter is used to decrease the speckle noise in radar images while simultaneously maintaining texture information. The enhanced frost filter is adapted from frost filter and it uses local statics (coefficient of variance) within individual filter windows. In this each pixel is divided into three classes, which are treated as following:-
   - **Homogeneous:** Pixel value is replayed by the average of filter window.
   - **Heterogeneous:** An impulse response is used as convolution kernel to determine the pixel value.
   - **Point target:** The pixel value is same.

5) **Kuan Filter:** Kuan filters are also used for reduction of the speckle noise while preserving the edges in radar images. It is used to alter multiplicative noise model into an additive noise model. This filter has features same as the lee filter but uses a different weighting function. The filtered pixel is then replaced by the value calculated which is based on local statistics. It was developed by Kuan, Nathan and Kurlander in 1987 [5]. It is local linear minimum mean square error filter and multiplicative noise. It is adaptation of Lee filter because it has no approximation involved. It is used to convert the multiplicative speckle model into the additive linear form.

6) **Gamma Filter:** It is also called Maximum A Posteriori (MAP) filter. It based on a multiplicative noise model including the non-stationary mean and variance parameters as well [11]. Gamma filters are used to reduce the speckle noise while preserving the edges in radar images. The gamma filter has similarities as the Kuan filter but assumes that the data gamma distributed. The pixel being filtered is converted into the value calculated on the bases of local statistics.

7) **Local Sigma Filter:** Local Sigma Filters are used to preserve the file detail (even local contrast areas) and to reduce speckle noise significantly. The local sigma filter uses the local standard deviation commuted to the filter box to determine the valid pixel within the filter window. It replaces the being filter with the mean calculated using only the valid pixel within the pixel box.

8) **Bit-Error Filter:** Bit-Error Filters are used to remove the bit error noise. The result of spikes in the data caused isolated pixels that have extreme value not connected to the image scene. The noise gives speckled image. Bit-error removal in ENVI uses an adaptive algorithm to replace spike pixels with the average of neighboring pixels. The local statistics (mean and standard deviating) within the filter box are used to set the threshold for valid pixels.

1.2 Discrete Wavelet Transform

Image Reconstruction with Discrete wavelet transform [8] used 2D version of the analysis and synthesis filter banks. In case of 2D (image), the 1D [9] [10] analysis filter bank that is first applied to the columns of the image and then applied to the rows. The method is based on two parts of progress. The first one is classic measure which computes smoothness of the image and relies on an approximation of the local Holder exponent via the wavelet coefficients and the novel measure takes account of geometrical constraints, which are generally valid for natural images [12]. The smoothness measure and the constraints are combined together first in a Bayesian probabilistic formulation. In the end they are executed as a Markov random field (MRF) image model.

2. NOISE MODELS

For easy framework of noise erase algorithm, before pre-processing for each type of noise a noise model should be studied. Speckle is a granular pattern more than that of noise. Intelligible combination of returned scattered energy and that of returned randomly conveyed scattered energy causes obstruction and at last presents dot clamour and it will record both sufficiency and stage estimations of back scattered radiation when all is said in done there are two fundamental methods of commotion as added additive and multiplicative. Added noise is deliberate, effectively displayed and can be expelled effortlessly with lesser efforts. Though multiplicative noise which is brought on by de-staged echoes from disperses is picture reliant, complex to display furthermore hard to diminish in spite of the fact that it contains valuable data [1].

Multiplicative speckle noise is in form of

$$L(q,1) = X(q,1)Y(q,1) \qquad (1)$$

Where $L(q,1)$ shows intensity format of corrupted SAR picture, $X(q,1)$ shows noise free SAR picture that has to be recovered or $Y(q,1)$ shows multiplicative speckle component. Logarithmic representation of multiplicative noise is in turn converted into additive noise which is given by

$$L(q,1) = X(q,1) + Y(q,1) \qquad (1)$$

Log transformation yields undesired effects in SAR in ages since mean of log transformed speckle is not zero. Speckle noise removal is a pre-processing task which contains segmentation that is detection and classification of SAR picture and presence of speckle affect radiometric resolution and make it difficult for human interpretation. So it is mandatory to remove speckle from SAR picture for picture processing community, for performing good post processing operations on SAR picture and for effective human interpretation too [1].

2.1 Advantages of digital image

- The processing of images is faster and more cost-effective. One needs less time for processing, as well as less film and other photographing equipment.
- It is more ecological to process images. No processing or fixing chemicals are needed to take and process digital images. However, printing inks are essential when printing digital images.
- When shooting a digital image, one can immediately see if the image is good or not. ƒ
- Copying a digital image is easy, and the quality of the image stays good unless it is compressed. For instance, saving an image as jpg format compresses the image. By resaving the image as jpg format, the compressed image will be recompressed, and the quality of the image will get worse with every saving. ƒ
- Fixing and retouching of images has become easier. In new Photoshop 7, it is possible to smoother face wrinkles with a new Healing Brush Tool in a couple of seconds.
- The expensive reproduction (compared with rastering the image with a repro camera) is faster and cheaper. ƒ
- By changing the image format and resolution, the image can be used in a number of media.

2.2 Disadvantages of digital image

- Misuse of copyright is now easier than it earlier was. For instance, images can be copied from the Internet just by clicking the mouse a couple of times. ƒ
- The value of the image will get worse? This has not necessarily happened everywhere. Images held in image banks still have reasonably good prices, inspite of the fact that downloading images through the net is fast and easy. The profitableness of digital photography has increased the number of images and photography in general. ƒ
- Old professions (such as maker-up, repro cameraman) vanish, and new ones do not necessarily appear. For instance in mid-1990s, the newspaper Aamulehti started using computerised make-up, and the traditional makers-up were left unemployed. ƒ
- Work has become more technical, which may not be a disadvantage for everyone. ƒ
- A digital file of a certain size cannot be enlargened with a good quality anymore. For instance, a good poster cannot be made of an image file of 500 kb. However, it is easy to make an image smaller.

2.3 Information Retrieval from SAR Image

After generating the raw image, the next step is to use raw back-scattering data (scattering matrix, [S]) and its derived products such as Coherency [T] and Covariance [C] matrices for each pixel of the image, as well as various Expectation-Maximization (EM) target decomposition algorithms, statistical techniques and digital image processing techniques in order to extract desired information about different target characteristics from the SAR image obtained in previous section.

LITERATURE SURVEY

[1] A Rajamani and V Krishnaveni in 2014 analyzed a survey of Various SAR Image Despeckling Techniques" consider various techniques of speckle reduction and their merits and demerits. A detailed comparative study of standard spatial domain speckle filters and wavelet domain speckle filters with respect to several metrics have been discussed. The recent developments using advanced image processing concepts such as patch similarity, statistical modeling, Graph cut methods total variation minimization method and compressed sensing methods have been presented. It has been planned to solve the limitations of increased computational complexity in a better way.

[2] Deepika Hazarika etal. in 2015 purposed "A Lapped Transform Domain Enhanced Lee Filter with Edge Detection for Speckle Noise Reduction in SAR Images" described methods which are used Lapped orthogonal transform (LOT) domain adaptive enhanced Lee filter for despeckling SAR images. For edge preservation during despeckling process, the modified ratio of averages (MROA) edge detector is applied to the approximation subband to obtain edge information which is then employed in the proposed framework to obtain edge information in other subband. The proposed despeckling filter shows significant improvement over enhanced Lee filtering in spatial and wavelet domain and also outperforms one recent undecimated wavelet domain method.

[3] Y. Murali Mohan Babu etal. in 2014 suggested that on De-Speckling of SAR Images" SAR images are degraded in quality by a noise which is known as "speckle". It is hard to remove the speckle noise using different techniques. The aim of despeckling of SAR images is to remove noise and to maintain the quality of SAR images. In this paper they concentrate on some major areas of de-speckling methods.

[4] G. Vasumath in 2015 Surved on SAR Image Classification" studied image classification which is an essential part of image processing. Synthetic Aperture Radar (SAR) is used to take high resolution images. SAR images produces speckle noise in its images due to the backscattering signal. It is difficult to classify when the image contain noisy content. The various steps of image classification are preprocessing, Segmentation, Feature extraction and classification. This paper gives the study about various methods and literatures of image classification steps include preprocessing, segmentation, feature extraction and classification.

[5] A.V. Meenakshi and V. Punitham analysis the performance of "Speckle Noise Reduction Filters on Active Radar and SAR Images" Reduction of speckle noise is one of the most important processes to increase the quality of radar coherent images. Image variances or speckle is a granular noise that inherently exists in and degrades the quality of the active radar and SAR images. Before using active radar and SAR imageries, the very first step is to reduce the effect of Speckle noise. This paper compares six different speckle reduction filters quantitatively using both simulated and real imageries. The results have been presented by filtered images, statistical tables and diagrams. Finally, the best filter has been recommended based on the statistical and experimental results.

[6] Naman Chopra and Mr. Anshul Anand "Despeckling of Images Using Wiener Filter in Dual Wavelet Transform Domain" In this paper comparison of two denoising method using adaptive wiener filter and fuzzy filter in wavelet domain is done. Wavelet transforms are specially used for compression, Denoising, Thresholding, Error reduction, reconstruction, and for image synthesis. Discrete wavelets transform and filters are used for image reconstruction in experiments. Performance can be calculated on the basis of two parameter i.e. PSNR (peak signal- to-noise ratio) & RMSE (root mean square error).

[7] A.Rajamani and V.Krishnaveni"Performance Analysis Survey of Various SAR Image Despeckling Techniques" Over the past four decades, the Synthetic Aperture Radar (SAR) imagery has become a beneficial and important application over the optical satellite imagery because of its ability to operate in any weather conditions. Thus, it has become essential to remove this speckle noise using suitable techniques. This paper presents the various important techniques available till date for the removal of speckle noise from SAR images and each technique with its own advantages and limitations are described. It also presents qualitative and quantitative measures of various techniques.

Table -1: COMPARISON TABLE

Sr No	Author Name	Title	Year	Method and Technology
1	AlinAchim et al, [14]	SAR Image Denoising via Bayesian Wavelet Shrinkage Based on Heavy-Tailed Modeling	2003	Maximum a posteriori (MAP) estimation
2	Aleksandra PizUrica et al. [15]	DespecklingSar Images Using Wavelets And A New Class Of Adaptive Shrinkage Estimators	2001	Wavelet Based Technique, wavelet coefficients
3	L.M. Kaplan et al. [16]	Analysis of Multiplicative Speckle Models for Template-Based SAR ATR	2001	MSTAR target chips, Rayleigh models
4	Y. K. Chan et al. [17]	An Introduction To Synthetic Aperture Radar (SAR)	2008	linear frequency modulation (LFM), matched filter response
5	YuanweiJin et al. [13]	Time Reversal Synthetic Aperture Radar Imaging In Multipath	2007	Time Reversal SAR (TRSAR), image formation techniques
6	R. Storvold et al. [18]	SAR Remote Sensing of Snow Parameters in Norwegian Areas — Current Status and Future Perspective	2006	Envisat ASAR, Snow water equivalent (SWE)
7	JONG-SF.N LEE [19]	Speckle Analysis and Smoothing of Synthetic Aperture Radar Images	1981	Statistical Technique, Local statistics noise filtering algorithm
8	Vladimir A et al. [20]	Synthetic Aperture Radar Image Classification via Mixture Approaches	2004	Markov random field approach, Cosmo-SkyMed and TerraSAR-X satellite sensors
9	FrédéricGalland et al. [21]	Unsupervised Synthetic Aperture Radar Image Segmentation Using Fisher Distributions	2009	Fisher probability density functions (pdfs), Fisher distribution
10	Michael J. Collins et al. [22]	On the Design and Evaluation of Multiobjective Single-Channel SAR Image Segmentation Algorithms	2008	Stewart algorithm (SA), Probability of false alarm (PFA) model

11	Ismail Ben Ayed et al. [23]	Multiregion Level-Set Partitioning of Synthetic Aperture Radar Images	2005	statistical modeling
12	Paul A. Rosen et al. [24]	Synthetic Aperture Radar Interferometry	2000	Geophysical applications, interferometry,
13	MüjdatÇetin et al. [25]	Feature-Enhanced Synthetic Aperture Radar Image Formation Based on Nonquadratic Regularization	2001	spotlight-mode synthetic aperture radar (SAR), random-phase nature
14	Carlo Colesanti et al. [26]	Investigating landslides with space-borne Synthetic Aperture Radar (SAR) interferometry	2006	Permanent Scatterers (PS), Liechtenstein
15	Klaus Hasselmann et al. [27]	On the nonlinear mapping of an ocean wave spectrum into a synthetic aperture radar image spectrum and its inversion	1991	real aperture radar (RAR) cross-section modulation,

3. CONCLUSIONS

SAR is a radar imagery technique provides important data regarding to earth's surface or subsurface. SAR is an active, day/night and all-weather remote sensing system. In this paper has studied various image processing techniques which are useful in despeckling of SAR image. The steps involved in image processing include pre-processing, segmentation, feature extraction and classification. Various speckle filters for SAR image are presented. For every components, image processing method with capacity to enhance performance in synthetic aperture radar systems were explained, and examples of successful or instructive methods from past were given.

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