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Comprehensive Survey on SAR Image Despeckling Techniques

Devi Devapal[1*], S. S. Kumar[2] and Christy Jojy[3]

[1]College of Engineering, Pathanapuram - 689696, Kerala, India; devidevapal30@gmail.com
[2]Noorul Islam University, Tuckalay - 629180, Tamil Nadu, India; kumar_s_s@hotmail.com
[3]Lourdes Matha College of Science and Technology, Thiruvananthapuram - 695574, Kerala, India; christy.annvincent@gmail.com

Abstract

Synthetic Aperture Radar (SAR) is a satellite imaging technology which produce high resolution images and can be used in varied atmospheric conditions. SAR obtains higher resolution remote sensing images from broad areas of terrain. It can be used day and night under all weather conditions. Unwanted data which affects the actual details of the image is called as noise. Inherent property of SAR is Speckle Noise of multiplicative nature which degrades SAR image quality. The backscattered echoes from objects undergo interference constructively and destructively which results in speckled image. The process of removing speckle noise is called as despeckling. The essential feature of despeckling technique is to effectively filter homogeneous areas while preserving textures and edges. The literature on despeckling methods for SAR images in both spatial and transform domain has been reviewed in this paper in chronological order.

Keywords: Despeckling, Speckled Image, Speckle Noise, Synthetic Aperture Radar

1. Introduction

SAR uses motion of antenna over the target scene. Sensors emit successive pulses of radio waves to illuminate the target and the echoes of the pulses are recorded. Signal processing of these recorded radar echoes results in SAR image. SAR produces a Two-Dimensional (2D) image. The two dimensions include range and azimuth. Range is the measure of straight line distance from radar to the object and azimuth is perpendicular to range. The azimuth resolution defines the sharpness of the beam. SAR images are used for Navigation and Guidance, Foliage and Ground penetration, Moving Target Indication etc.

Speckle is a noise-like variation in contrast. It arises due to the variations in the strength of the reflected echo waves from the target and is seen mostly in SAR and Ultra Sound images. Speckle noise occur as granular pattern formed by the interference of randomly scattered energy which occurs when object illuminated by coherent radiation have rough surface. Speckle noise causes difficulties for image interpretation and further processing of the image. The speckle is multiplicative in nature which makes the process of noise removal more complicated. The ideal speckle reduction technique preserves the edges and other textural information.

2. Speckle Reduction Techniques

Speckle noise reduction can be carried out either in the spatial domain or in the transform domain. Filtering in spatial domain consists of moving a window over the image pixel by pixel and substituting the value of the central pixel with a mathematically derived value until the entire image has been covered. This results in a smoothing appearance and reduces the speckle noise. In transform domain filtering coefficients are given threshold values for noise removal. Due to the energy compaction

**Author for correspondence*

property large amount of information is contained in a small portion of the transform coefficients. These schemes are complex and lack an effective noise model and hence are difficult in finding out a threshold for noise removal. This section reviews the standard speckle reduction techniques.

Lee et al.[1], utilized the values of the neighborhood pixels in the kernel. Here each pixel is independently processed. That is the local statistics of the pixels within the moving kernel are taken into consideration. Here the weight function is calculated by Minimum Mean Square Error (MMSE) estimator. This filter suppress the speckle noise efficiently but it over smooth the details in the image.

The Frost filter[2], is an adaptive and exponentially-weighted averaging filter. Here an optimum minimum MSE filter is used for smoothing images. The locally estimated parameter values of mean and variance are used to make the filter adaptive and to provide minimum MSE in homogeneous areas. It is designed to smooth out noise while retaining edges or shape features in the image. The kernel is adaptive to the local structure in the image and hence is an adaptive filter. The drawback is blurring the details.

The method by Kuan et al.[3] is an extension of Lee's algorithm. Kaun is an adaptive noise smoothing filter. It adapts to local changes in image statistics based on a Non-stationary Mean, Non-stationary Variance (NMNV) image model. The advantage of this method is its ability to deal with various types of noises which depends on signal characteristics. Also prior knowledge about the actual image is not required. The drawback of Kuan filter is over smoothing of edges and textures.

Baraldi et al.[4] proposed refined Gamma Maximum-A-Posterior (RGMAP) method which is a modified version of Gamma Map. It accommodates a shape adaptive window near image contours rather than using a rectangular window. This method uses segmentation box for finding image edges and apply filter box to each segments. The contribution of this paper is that it improves the ability to adapt to shape near the image contours and preserves edge sharpness but ignore the textures resulting in blurred textures.

Gagnon et al.[5] proposed a wavelet de-speckling approach based on Symmetric Daubechies (SD). It modifies the noisy wavelet coefficients according to the shrinkage rule and reconstructs the filtered image from it. Here the Elliptical soft-thresholding procedure is used as the filtering technique. After performing the logarithmic transform and an N level SD transformation of the image it calculates its mean and covariance. Then the inverse wavelet and logarithmic transforms are performed. In order to minimize articrafts cycle spinning algorithm is implemented which averages the result of all WCS filter over all possible shifts of input image. This method suppresses the speckle noise to a better extend, but results in increased computational load. A wavelet de-speckling method based on Bayesian shrinkage which relies on edge information has been proposed in[6]. The noise-free wavelet coefficients are estimated from a bayesian wavelet shrinkage factor. Edge information is obtained using a modified ratio edge detector. This obtained information is further used in the despeckling process to preserve edges.

Chitroub et al.[7] proposed K-Distribution to model SAR images. The parameters are derived using a combination of the bootstrap sampling method coupled with the Monte Carlo technique. Mellin multiplicative convolution is used to deduce K distribution models. The K distribution parameter estimation in this paper is effective, but implementation is not so practical.

Achim et al.[8] proposed an adaptive MAP estimator with a heavy-tailed Rayleigh signal model. The multiplicative speckle is converted into additive by applying a logarithmic transformation. The Received Complex Signal (RCS) is modeled using heavy-tailed Rayleigh density function. Here the real and imaginary part is assumed to be best described using the alpha-stable family of distribution. Second-kind statistics theory, which relies on the Mellin transform, is used to estimate the model parameters from noisy observations.

Bianchi et al.[9] proposed an algorithm which relies on the GG distribution. The algorithm is based on undecimated wavelet decomposition and MAP estimation. This paper presents an approach for classifying the wavelet coefficients based on their texture energy. Based on the degrees of heterogeneity the wavelet coefficients are classified into different classes. This despeckling scheme is an improvement to the locally adaptive GG modeling. The expressions for estimation of GG parameter is derived exactly. The major drawback is that it suffers from computational cost due to undecimated wavelet transform.

Subrahmanyam et al.[10] proposed a scheme based on the Kalman filter. Kalman filter in its normal form is appropriate for additive noise. Since speckle is a multiplicative noise, unscented transform of Kalman filter is taken called as Unscented Kalman Fiter (UKF). To account multiplicative noise discontinuity-adaptive Markov conditional PDF is introduced. The first two moments are estimated through importance sampling and hence called Importance Sampling Unscented Kalman Filter (ISUKF). Sigma points are used to capture the noise characteristics, and are propagated to arrive at the final image estimates. The use of a discontinuity adaptive MRF avoids over-smoothing of edges.

Jarabo et al.[11] introduced a despeckling algorithm based on the mean shift algorithm. This algorithm converges near a point where the probability density function estimator gradient is zero. Hence the algorithm is called a gradient based adaptive method. This technique reduces the speckle noise to a great extent but it blurs the edges to some degree which affects the output estimation.

Liu et al.[12] proposed anisotropic diffusion method based on an adaptive window. Here an adaptive rectangular kernel with both variable size and Orientation is adopted to calculate the local variance of the pixels. Then the anisotropic diffusion based on a novel diffusion coefficient is proposed to smoothen the noise along with preserving the edges and textures of the image. This paper proposes an adaptive windowing scheme where the window can be varied according to the local structure so that the pixels around the edges have little influence on the pixels on edges. And the new diffusion coefficients make the process more stable. This method suppresses speckle noise and preserves image details but leads to edge blurring.

Wu et al.[13] proposed an algorithm that uses combination of wavelet and curvlet soft thresholding method and then takes the difference between the obtained two images. Then the curvelet soft thresholding method is employed to the residual image and the curvelet denoised residual image is added to the previously denoised image. This method is able to suppress the speckle noise efficiently and preserves fine edges. The major drawback is that it produces blurring effect on the image.

Ma et al.[14] proposed a method for despeckling in the directionlet domain which is based on Gaussian Scale Mixtures (GSM) model. Here the actual image is being divided into smaller sized segments and then perform logarithmic transforms. Then the direction of texture of each segment is computed following edge map. The transformed image is decomposed into the subbands using directionlet transform. The denoising is performed in each subband by Bayesian Least Squares (BLS) estimator and at last, reconstruction is conducted. The advantage of this method is that it takes into consideration the intra-scale dependencies on the image and is based on local statistics. The drawback is that this method results in over-smoothing of homogeneous areas.

Hebar et al.[15] proposed an Auto Binomial Model (ABM) to model a prior probability density function. The model for approximating texture features are derived by using second-order Bayesian inference. The region-borders are used to detect the edges. Homogeneous and heterogeneous areas are distinguished by using coefficient of variation. The ABM proposed in this paper can capture the textures clearly. The parameter estimation results in high computational cost.

Christy et al.[16] proposed improvement to the existing Non-Local Means Filtering (NLMF) Technique. A discontinuity adaptive Non Local Means Filtering (DA-NLMF), which uses a discontinuity adaptive weighting function, is used in order to preserve the edges and fine structures more effectively than the basic Non Local Means, which uses a Gaussian weighting function. It exhibits better edge preservation capability, without compromising the homogeneous areas. This DA-NLMF is used as an effective post processing technique along with Importance Sampling Unscented Kalman Filter (ISUKF) for despeckling SAR image. The proposed method for de-speckling SAR imagery by combining ISUKF and DANLMF gives better result than each once used individually.

3. Conclusion

SAR is a radar imagery technique which gives useful information about earth's surface and subsurface. SAR is an active, day/night and all-weather remote sensing system. Inherent with SAR imageries is speckle noise which is formed due to the interference of backscattered echoes. The SAR despeckling can be done in either spatial or frequency domain. This paper reviewed the different SAR despeckling techniques in spatial and transform domain in the chronological order. From the review it can be concluded that both spatial and frequency domain has its own merits and demerits .So combination of these methods would be better for despeckling SAR images.

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