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A Survey on Despeckling Of Synthetic Aperture Radar Images

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Abstract— Synthetic Aperture Radar (SAR) is a technology used for producing satellite images with high resolution. Since few decades SAR imagery has been the most famous and prominent thing in the context of earth's observation because of its capability of penetrating through the soils and clouds. Also, SAR imagery has a good ability to operate at any condition type of weather during days and nights. In Remote Sensing technology it is playing a vital role because of this capability and ability. But the presence of undesirable data influences the actual details of the SAR image. This undesirable data is called as noise. This specific noise is also called as "Speckle". The SAR images are corrupted by the presence of this strong noise. Over few years many techniques have been used to remove the noise from SAR imagery. This process of removing the speckles or noise from SAR imagery is called as Despeckling. In this paper, different methods which are used for removing the noise are discussed.

Keywords—Synthetic Aperture Radar, Speckle, Despeckling

I. INTRODUCTION

Synthetic Aperture Radar (SAR) imagery provides information by penetrating the clouds and earth's soil and the ability to operate in any type of condition of weather. These are the advantages of SAR imagery in providing the information of earth. Apart from these advantages it has a disadvantage, that is, it consists of strong noise called speckles in their images which affects the quality of SAR images. SAR images are used in remote sensing technology. Microwave remote sensing and optical remote sensing are the two types of remote sensing technology in which infrared, visible frequencies and radio frequencies are used respectively.

After the SAR images are despeckled by removing the noise, the analysis of the image is done by studying the textural content, and the objects and boundaries in the image are identified. In this paper, different types of techniques for despeckling are discussed detailed with its advantages and disadvantages. Though there are many algorithms the researchers have come up with from years, still they are trying to find out a challenging and a very efficient algorithm.

NOISE MODEL**:** The different types of noise models are studied to make the process of applying the noise removal algorithm easier. Speckle does not exactly mean Noise but it is that which more of a granular pattern is. There are two kinds of noise models which are Multiplicative noise and Additive noise. The additive noise is removed easily without much effort because it is easily modelled and systematic. Multiplicative noise contains useful information but it is difficult to remove because it is a complex model.

My contribution to this survey paper, "A Survey on Despeckling of Synthetic Aperture Radar Images" is I have surveyed few of the IEEE papers from the year 2013 to 2018. I focused to take the papers which mainly concentrated on removing the noise from SAR images. In all these papers, authors discussed different techniques for deducting the noise to get the speckle free image as output. I have discussed those techniques in brief below.

The organization of the paper is as follows, Section I contains the introduction of SAR image Despeckling. Section II contains the various techniques for removing the noise from SAR images. Section III contains a tabular form in which all the methods discussed in Section II are compared. Section IV concludes the survey work of SAR image Despeckling.

II. TECHNIQUES FOR THE REMOVAL OF SPECKLE NOISE FROM SAR IMAGE

Speckle filtering is done for three main purposes. They are: removing the noise in uniform regions, enhancing and

preserving the edges without any changes in features, and providing good visual appearance.

There are two techniques which are widely used for SAR image speckle reduction, namely Multilook processing technique and Adaptive image restoration technique. Multilook processing technique uses the digital image processing either in spatial domain or in frequency domain. This technique averages many independent images. The drawback of this technique is, the computation increases when the number of independent images increases and also the images' resolution decreases when the smoothing is performed on uniform areas. The two advantages of this technique are it performs good image sharpening and contrast enhancement in better way. Also it has disadvantages, it moves to the boundaries while performing sharpening and information of frequency is not obtained and it just manipulates only pixel. Whereas the Adaptive image restoration technique uses filters like Local statistics filters, Lee filter, Maximum a Posterior filter (MAP), Point wise linear filter.

2.1 CNN

In 2017, authors named G. Chierchia, D.Cozzolino, G.Poggi, L.Verdoliva introduced [3] Convolutional Neural Networks for despeckling of the SAR imagery. The network uses a strategy called residual learning, so the speckles are subtracted from noisy image but the filtered image is not recovered. Multitemporal SAR images are considered to perform the training. In the recent years, many researchers proposed CNN based models for denoising of Additive white Gaussian noise (AWGN). But this author introduced residual learning strategy. There are 17 full convolutional layers without pooling in this proposed CNN architecture. In this network the speckle component is recovered first from the noisy image and then subtracted from it.

2.2 RED-NET

In 2017, the authors named FengGu, Hong Zhang, Chao Wang, Bo Zhang introduced[6] RED-NET to despeckle the SAR image. The expanded form of RED-NET is Residual Encoder-Decoder Network. This encoding decoding framework is introduced based on the deep convolutional network. A series of Deconvolutional and Convolutional layers are consisted by this network. This network is able to preserve the details of image.

In recent times, CNN is used to remove the noise. CNN is a powerful tool which contains 7 Convolutional layers. The RED-NET architecture consists of 13 deconvolutional layers for decoding and 15 Convolutional layers for encoding. In this paper they concluded that their proposed method can obtain effective and better performance than classic convolutional neural networks (CNNs).

2.3 Boostrapping method:

In 2017, Yaser Arianpour proposed[1] a new technique for despeckling and for the super resolution approach (SR approach) for the SAR images.in this method, the SAR image with speckles low resolution is transferred to Gradient domain and all the edges sharpness is extracted. The author used Bootstrapping approach and also Zernike moments to get the new edge sharpness values. The noise free SAR image with high resolution is obtained with these new values of the edges sharpness.

2.4 Combinational regularization model

In 2017, GaoChen, GangLi, YuLiu, Xiao-PingZhang, LiZhang proposed [2] a model of Combinational regularization for despeckling of SAR images. Many of the familiar regularization method use only one image priority property whereas this proposed method includes Non-local rank regularization term (NLR) and Fractional order total variation regularization term (FrTV). This model is used to remove the noise from the homogeneous areas in an image and also it is used to preserve the geometrical features and edges when the despeckling process is carried out for a noisy image. This model is used for removing the noise from a Synthetic Aperture Radar image and it is also used to preserve the texture of an image. In the proposed model, a method is derived called Alternating Direction Method which solves the optimization problem very efficiently. For a Synthetic Aperture Radar image the despeckling process is a vital job. In the previous decade, Total Variation Based Regularization model is proposed. This model is most successful in image edges preservation but it does not preserve the textures. In order to solve this problem, that is, to preserve the textures a new model is proposed which is called as non-local fractional order totla variation regularized model. This FrTV model also has a drawback which is that the algorithms of this model cannot recover fine structure or some small point kind of things. The reason for this is it cannot find the most common thing in SAR images called non-local self-similarities. This problem is solved by a method called non-local means by the exploitation of self-similarity for denoising a SAR image. Because of this exploitation the non-local regularization algorithms can perform the despeckling process more efficiently than local regularization algorithms.

2.5 NTV regularization model

In 2018, the authors named Qingjun Zhang, Tengfei Li, Yu Zhu, Zheng Lv proposed[4] a method for SAR image Despeckling called "novel total variation (TV) regularization model". Here the reconstruction and despeckling of SAR images are done by a method in which second order total variation and fourth order total variation sparse constraints are combined and applied. The image reconstruction by total variation regularization model was introduced by Rudin, Osher, and Fatemi. Here in the proposed paper they mainly

focused on preservation of details and despeckling of SAR images. Though the algorithms named Basis pursuit and Orthogonal matching pursuit can restore the image quality, the ability of detecting the target and the quality of image is very poor. Hence to solve this problem the Novel TV regularization model is proposed. By using this method the image features details are preserved while it is despeckled in a more efficient manner. The proposed novel TV regularization model for despeckling the SAR image is a combination of fourth order and second order TV sparse constraints which are applied to SAR image for removing the speckles and reconstructing it. The proposed fourth order and second order TV method ignores the drawbacks of fourth order and second order constraints which consists of "edge blurring" and "block effect" respectively. In the near future the SAR image despeckling based on High order TV regularization produces good values in many applications of Image processing and military and civilian microwave signal.

2.6 ATV regularization method

In 2013, the authors named Yao Zhao, Jianguo Liu, Bingchen Zhang, Wen Hong, Yirong Wu proposed [9] a paper with "an adaptive total variation regularization method for SAR image despeckling". At first the SAR image is taken and the noise level is calculated based on the analysis of wavelet. After that the parameter of the tv regularization which is adapted is exploited depending on the calculated noise level. At last, to solve the TV regularization dual formulation a method is proposed which is semi implicit gradient decreasing method. The authors concluded that their proposed method can suppress the speckles more effectively without any compromise in the image features edge sharpness.

2.7 Low-rank representation algorithm

In 2016, the authors named Jie Geng, Jianchao Fan, Xiaorui Ma, Hongyu Wang, Ke Cao proposed [5] an algorithm for despeckling of SAR images, which is called "an iterative low rank representation (LRR) algorithm". Here first the SAR image is converted to logarithmic form and after that it is filtered iteratively by using their proposed model low rank representation algorithm. In every iteration, similar patches are formed into a group. Next, by using the nuclear regularized low-rank representation the patches are filtered. Lastly, the denoised image is formed by combining all those filtered patches.

It is necessary to remove the speckles because speckle reduces the quality of Synthetic Aperture Radar imagery. To solve this issue many number of despeckling methods are proposed to increase the performance in many number of SAR image processing applications. The first despeckling technique is mainly depended on spatial-domain filtering. Tranform-domain filtering is adopted widely to remove the speckles, later with improvement in despeckling techniques. In recent times, LRR is widely applied for denoising an image.

2.8 ASRDA

In 2015, the authors named Zhenchuan Pang, Guanghi Zhao, Guangng Shi, Fangfang Shen proposed[8] a "Adaptive Sparse Representation based SAR Despeckling Algorithm (ASRDA)". In recent times, Sparse representation has got great attention in the research of image denoising. But this SR model is not able to preserve the details of the image. Therefore, in this paper they joined new SR model and AR constraint to get good results and to get lifted objective function. This helps in preserving the details of an image. Here, the speckle component is observed as the coefficient residual and this is made equal to the difference between the evaluated coefficient and the real image coefficient. In addition, the nonlocal similarity and the autoregressive model are combined to identify the details of the image efficiently.

2.9 KNN algorithm

In 2015, the authors named Aiyeola Sikiru Yommy, Rongke Liu, Spencer Ojogba Onuh and Ani Cosmas Ikechukwu proposed[10] a paper to despeckle the SAR image where they used K-Nearest Neighbour (KNN) algorithm. This algorithm is used to improve the performance of Lee filter by modifying it. When the existing filters are used some problems arises like blurring, edge preservation and feature preservation. So this method is used to introduce a modified filter which can avoid these problems. Using this method filtering parameters is calculated by selecting the nearest neighbour pixels. When using this method the window size should be only 5x5 and when fifteen out of twenty five pixels are used then only the good result is obtained. Before compressing the SAR image using "Two-Dimensional Discrete Wavelet Transform (2-D DWT)", the modified or improved filter is applied. In this paper it was concluded by their simulation result that, if the despeckling of SAR image is done before compression then the better results can be obtained.

2.10 GGF-BNLM

In 2016, the authors Weiping Ni and Xinbo Gao proposed[7] an extended scheme for despeckling which is known as "generalized guided filter with Bayesian nonlocal means (GGF-BNLM)". The main contributions in this paper are: for this proposed GGF-BNLM method they reduced the nonlinear weight kernel successfully and using maximum likelihood rule and homogeneity analysis of local regions they successfully constructed the guidance image. SAR images are widely used in different fields because of its usability in different conditions of weather. But these are corrupted by multiplicative noise because of the backscattered radar echoes interference. This results in the degradation in resolution of SAR images by which the

analyzing of SAR image, its interpretation and processing becomes difficult. Hence, despeckling is a primary thing for a SAR image.

In general, the methods for suppressing the speckles are classified into two types, which are filtering methods and multilook processing. In the paper, the quantitative and visual experiments done on synthetic and real SAR imagery showed that their method decreases the noise with unperceivable detail blurring with good protection for point-type strong scatters. They concluded with their paper that their proposed method performs better than many classical and modern methods.

III. COMPARISON OF ALL THE ABOVE DISCUSSED METHODS:

S.NO	YEAR	AUTHOR NAME	METHOD/ALGORITHM NAME	REMARKS/LIMITATION, ADVANTAGES
01	2015	Ojogba Onuh, Spencer	K-Nearest Neighbour algorithm (KNN) [10]	The time of computation is decreased in this method. Image details are lost and blurred image is resulted when the big sized window is selected.
02	2013	Bingchen Zhang, Yao Zhao	adaptive total variation (ATV) regularization method [9]	Effective preservation of images and sharpness of edges is done by the proposed method and it successfully supresses speckles from SAR image.
03	2015	Fangfang Shen, Guanghi Zhao	Adaptive Sparse Representation based SAR Despeckling Algorithm (ASRDA). [8]	The method which is proposed here is not much effective on extremely affected images
04	2016	XinboGao, Weiping Ni	Generalized guided filter with Bayesian nonlocal means (GGF-BNLM) [7]	To make the algorithm more robust it is necessary to seek analytical expressions
05	2017	Chao Wang and Feng Gu	Residual encoder decoder network (RED-NET) [6]	Good improvements are achieved in time efficiency and despeckling performance over the modern despeckling methods.
06	2016	Xiaorui Ma, Ke Cao	Low-rank representation algorithm [5]	The better visual effect is performed by the proposed algorithm which is more effective than other algorithms. The proposed method is little inferior to SAR-BM3D, which produces the strongest edge preservation.
07	2018	Zheng Lv, Tengfei Li	Novel total variation regularization model [4]	High-order TV regularization based SAR image despeckling method will produce great value in many civilian and military microwave signal and image processing applications in the near future. According to subjective visual assessment of image quality and objective evaluation, the image details are not compromised while effective suppression of speckles is performed
08	2017	G.Poggi, D.Cozzolino	Convolutional neural networks, ADAM optimization algorithm [3]	Limitation: During training only the well despeckled ones are seen but not the clean patches.
09	2017	Li Zhang, Gao Chen	Combinational regularization model [2]	Improved results of Despeckling are obtained and the texture and edges details are preserved effectively.
10	2017	James A.ritcey, Yaser Arianpour	Gradient based Zernike moments, Boostarpping method [1]	High desirable results are produced with proper suitable resolution and suppression of speckle.

IV. CONCLUSION

In this survey paper the brief discussion of the techniques is done from the papers belonging to SAR image despeckling from the year 2013 to 2018. A SAR image is an important thing by which the earth's surface crucial data is obtained. It is used in many applications in different fields like resource mapping, military, oceanology, agriculture etc. but a SAR image definitely contains lot of speckles in it by which it becomes difficult to analyse the image very accurately and precisely. So, to remove these speckles many authors introduced many techniques to make the image noise free. Few of them were discussed in brief and compared their properties in this paper.

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