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A conventional and non-conventional analysis of SAR image despeckling technique

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Abstract. The importance of high-resolution Synthetic Aperture Radar (SAR) imaging is undeniable in applications for Earth monitoring since it offers useful data for analysis. Post-image processing methods including edge and object detection, segmentation, and speckle noise removal are important to performed to find the information of images. The key technique that makes images aesthetically pleasing and understandable is despeckling. The presented study assays the latest trends & state of the art techniques for SAR image despeckling to gauge the performance & agility of existing techniques by performing a contemporary combination of theoretical & experimental analysis. This study analyses various techniques used in literature. The quantitative & qualitative analysis is done using Peak Signal-to-Noise Ratio (PSNR) and Universal Image Quality Index (UIQI) indices to find the better approach.

Keywords: SAR image despeckling, speckle noise, PSNR, UIQI, noise reduction.

1. Introduction

The important application of radar is imaging radar, which produces 2-dimensional images, usually of landscapes. It illuminates a region on the ground and takes picture at radio wave. Radar imaging techniques can be primarily classified into two parts which are shown in Figure 1 i.e., Real aperture radar (RAR) and SAR. A major hurdle while working with SAR images is that they are adversely corrupted by multiplicative noise from the interactions of emitted radiations in granular pattern, known as speckle, which corrodes image clarity, resolution & details among other at- tributes. The intensity of noise in each pixel is known as speckle pattern. Despeckling using filtering technique in SAR image is shown in Figure 2. The research [1-6], gives an empirical study of different filtering techniques that offer the best results in SAR image despeckling which include:

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- Adaptive Speckle reduction filter- Structured to remove noise while preserving the edges [15].
- Conditional Averaging Filter– Linear scaling of pixel intensities implemented to eliminate noise [16].
- Speckle Reduction Filter – For Multiplicative and additive noise filtering, for fast image processing systems and one-dimensional Processing for image restoration [17-19].

The presented research is divided as follows: Section 1 introduces a concise study of satellite imagery, its categorization, and the importance of despeckling in SAR images. Section 2 provides an overview of the related work of the existing methods and techniques to despeckle SAR images. Section 3 gives an empirical and experimental result analysis of SAR images. Finally, we derive conclusion and outline possible future work in Section 4.

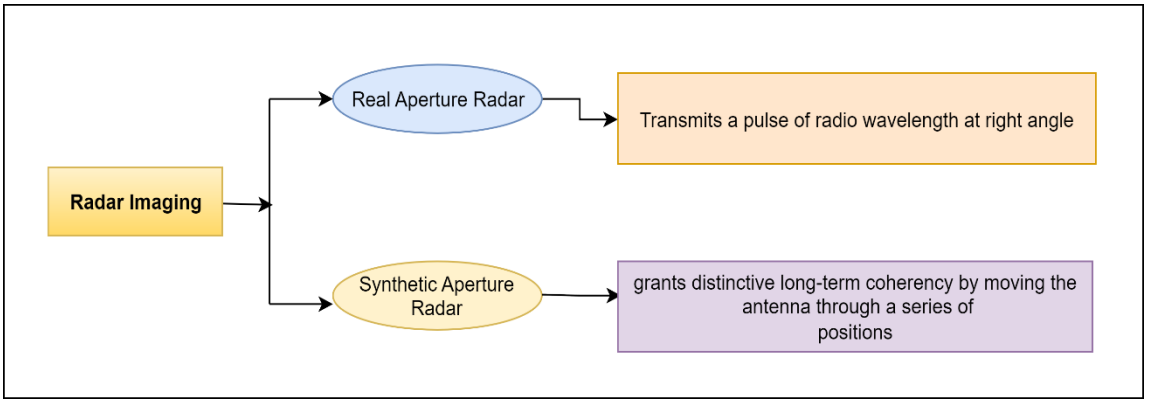

Figure 1. Types of radar imaging [3].

Figure 2. Despeckling using filtering technique in SAR image [19].

2. Literature survey

The aim, techniques used, their advantages and disadvantages are briefly discussed below in Table 1.

Table 1. Literature Survey in tabular form.

Reference No.	Aim & Technique	Advantage	Disadvantage
Vitale et al, 2019 [1]	Propose a deep learning-based SAR image despeckling method without compromising on detail preservation, it also solves the issue of paucity of data by training model on stimulated data.	• Addresses the paucity of data. • Performed tenable despeckling while preserving details & edges. • Validation for both stimulated & real data.	• Comparative analysis is missing, leaving the reader assuming the improvement when compared to other techniques

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Table 1. (continued).

Vitale et al, 2019 [3]	Optical imagery information is used to perform optimized SAR despeckling via non-local path wise filtering, such that filtering weights are influenced by tips from optical guide.	• Addresses the problem of filtered image. • Outperforms classical optical guide filters by substantial value.	• Requires user to manually register the optical imageries & guide, post obtaining the same from legit sources.
Chierchia et al, 2017 [5]	This study uses non-local filtering by extending the SAR-BM3D approach, implementing concepts of block-matching and collaborative filtering	• It displays tenable performance in real multi temporal SAR images. • Due to use of look up tables for distance calculation, the framework poses to be cost efficient.	• Comparative analysis & parameters are limited in nature, posing the research to be insular in nature.
Cozzolino et al, 2012 [7]	A non-local mean filtering technique is proposed where weights of neighbouring pixels are assigned by Convolutional Neural Network (CNN) for despeckling of SAR imageries.	• It leverages the advantages of non-local mean filtering i.e., includes hidden signal by exploring self-similarities of image. • Performance is cogent.	• The multi-step use of CNN and then rectifying adds complexity to the framework. • Finding apt non-local filters is an abstruse task.
Zhao et al, 2018 [9]	Proposes a despeckling method of SAR images based on the concept of "super image", instead of multiple image filtering, a super image or stack of image is filtered by ratio. Ratio images or homogenous images are filtered by suppression of speckle.	• Gains advantage by reducing the computation complexity via processing stack of images in one go. • Leverages performance obtained by optimized spatial stationarity of ratio imageries. The results preserve texture & details with improved despeckling.	• The frameworks claim to outperform all classical method but compares its performance with only MSAR-BM3D and 2SPPB. Posing the study to be insular in reach.
Liu et al, 2017 [10]	SAR despeckling is performed by using optimized Nonlocally centralized sparse representation (CSR), via the consideration of an extra nonlocal sparsity constraint terms.	• The manipulation in technique based on projected coefficients provides natural boast in performance to the technique & the freedom to choose appropriate denoising technique.	• The adapting nature of technique adds to the computation complexity & creates ambiguity in the process.
Chierchia et al, 2017 [12]	SAR image despeckling is performed via the application of residual learning by implementing CNNs. Network is trained on a large multi temporal SAR image with multi look feature.	• The results obtained show substantial improvement both on qualitative & quantitative aspects, with preservation of resolution, texture, edge, details & image quality.	• Training the network is extensive in work & intensive in time. In future paucity of multi temporal data can arise to make the technique weak & dependent.

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Table 1. (continued).

Tang et al, 2019 [13]	Amalgamates multilayer perceptron (MLP) neural-network model with time series for despeckling of SAR images, trained with archived images to self-learn automatically adjust weights.	• The framework can self-train & manipulate the weights for enhanced performance, with error reduction using back propagation scholastic gradient.	• Though the comparison is made with latest techniques, but the parameters used to do so are limited.

3. Experimental results and discussion

Radar imaging is a category of satellite imagery which creates two-dimensional and three-dimensional images, typically

3.1. Comparative qualitative analysis

In this section, experimental results of the various algorithms studies along with some images are presented to provide evidence for the effectivity of the same. The SAR image used for the analysis has been shown in Figure 3, while the output of the qualitative analysis is shown in figure and Figure 4. The specification of the image is shown in Table 2.

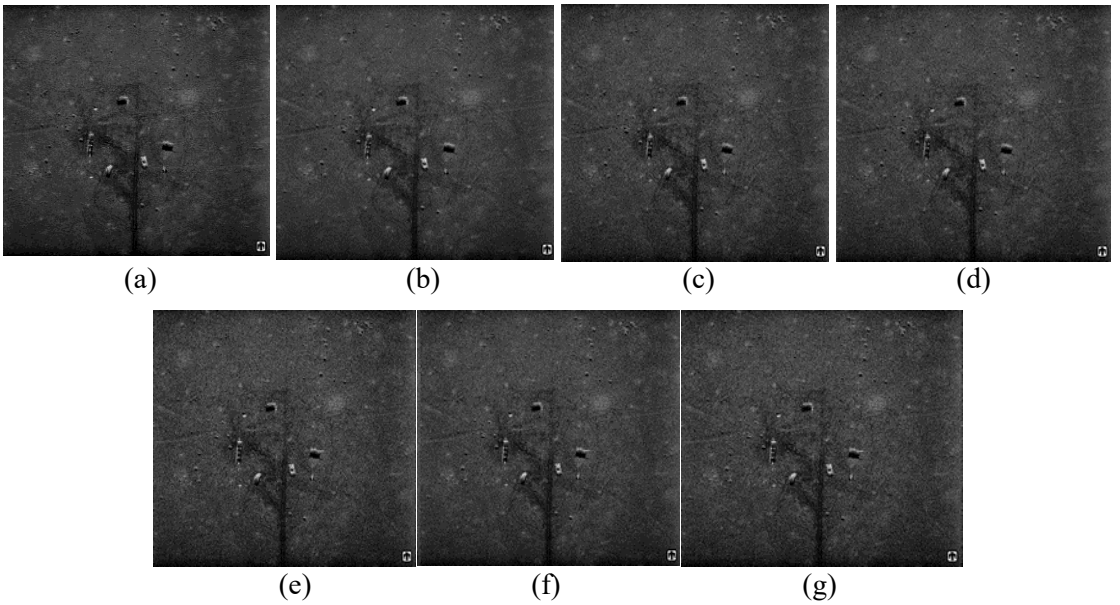

Figure 3. (a) SAR image used for evaluation (b) Results of [11] (c) Results of [9]. (d) Results of [7] (e) Results of [8] (f) Results of [1] (g) Results of [14]

Six of the widely used state of the art speckle noise removal techniques namely [11][9][7][8][1][14], have been compared against each other. Amongst them,[11] gave the best visual result with a noticeable decrease in the noise and some significant recovery of the details present in the background of the image.

Table 2. Specification of the images.

Component	Specification
Noise (Artificially added)	5%
Resolution	512x512

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3.2. Comparative quantitative analysis

The Peak signal to noise ratio can be defined using mean square error. If we have Image *Y* of *mxn* resolution and its noisy approximation its noisy approximation *Y*, then Mean square error is defined as given in *equation 1*.

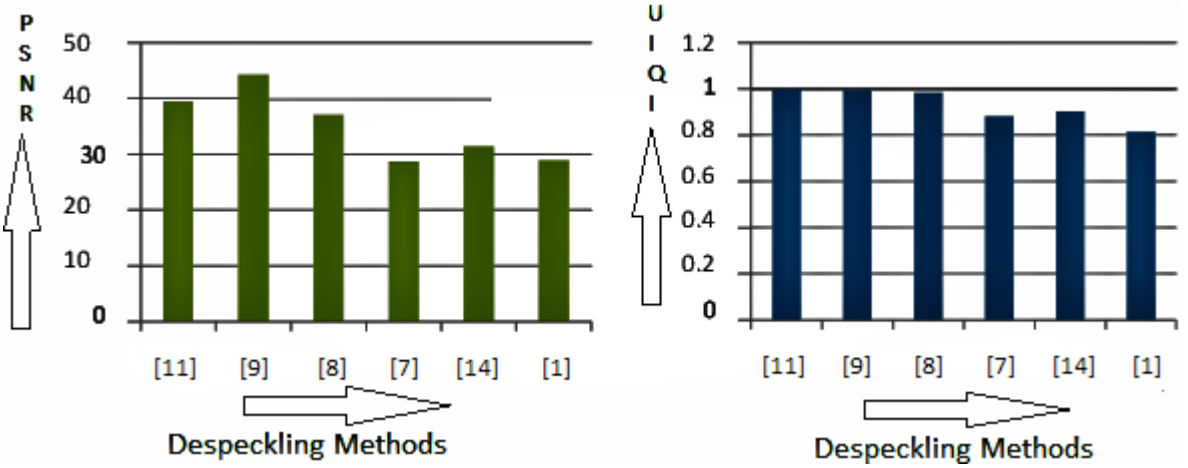
$$Mean\ Square\ Error = \frac{1}{mn}\sum_{k=0}^{a-1}\sum_{l=0}^{b-1}[X(k,l) - Y(k,l)]^2 \quad (1)$$

The PSNR value is calculated using equation (1). $PSNR = 10.log_{10}(\frac{Maximum_I^2}{Mean\ Square\ error})$, where Maximum is maximum pixel which is possible in image.

Table 3. Average PSNR, and SSIM values of despeckling techniques.

	[11]	[9]	[8]	[7]	[14]	[1]
PSNR	39.567	44.679	37.223	28.97	21.887	29.251
UIQI	0.978	0.921	0.981	0.854	0.861	0.817

A set of 12 images were used to measure the accuracy of the techniques, leveraging commonly used image metrics such as PSNR, and UIQI. In most of the cases, [11] gave the highest result with [9] at a close second. A set of 12 images were used to measure the accuracy of the techniques, leveraging commonly used image metrics such as PSNR, and UIQI. In Table 3 as shown above, the data of the average of all the frameworks across all the techniques have been laid bare for perusal. Figure 6 shows the average values of the scores by the 6 techniques for different metrics applied across the entire dataset. This is done mainly to conserve space as inclusion of 48 graphs to represent all techniques across all the images is out of the scope of this paper. From Figure 6 it is clear that [9] has the highest PSNR meaning it has the least amount of noise present.



(a) (b)

Figure 4. Quantitative despeckling results (a) Average PSNR values (b) Average UIQI values.

The lower value of noise makes it a good candidate for producing a high-quality image, although the recovery of detail and the smoothening of artifacts are two factors not considered in this metric. UIQI being a less strict metric gave similar scores to all the techniques across the board. Both [11] and [9] got average scores above 0.99 which shows high level of despeckling but makes comparison less accurate. Only in this case [1] performed markedly worse than the others with a score of just 81%. The cause for this is attributed to a change of contrast in all images processed using [1].

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4. Conclusion and future scope

The exhibition of the proposed technique is surveyed by the visual appearance of the despeckled SAR picture and with the assistance of quantitative measurements like PSNR, and UIQI. From the censorious comparative, theoretical and empirical analysis, it tends to be said that Adaptive speckle reduction filter technique preserves the edges and structure of the image while SAR image despeckling and is comparatively superior technique considering the assayed literature & methodologies. This exploration shows that no visual ancient rarities are produced during the cycle. Subsequently proposed strategy has the likely capacity to be utilized in different pragmatic application of SAR images despeckling like, remote sensing and mapping of surfaces of globe.

References

[1] Vitale, S., Ferraioli, G., & Pascazio, V. (2019, July). A New Ratio Image Based CNN Algorithm for SAR Despeckling. In IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium (pp. 9494-9497). IEEE.

[2] Singh, P., & Shankar, A. (2021). A novel optical image denoising technique using convolutional neural network and anisotropic diffusion for real-time surveillance applications. Journal of Real-Time Image Processing, 18(5), 1711-1728. doi:10.1007/s11554-020-01060-0

[3] Singh, P., Diwakar, M., Shankar, A., Shree, R., & Kumar, M. (2021). A review on SAR image and its despeckling. Archives of Computational Methods in Engineering, 28(7), 4633-4653. doi:10.1007/s11831-021-09548-z

[4] Zhang, Qiang, Qiangqiang Yuan, Jie Li, Zhen Yang, and Xiaoshuang Ma. "Learning a dilated residual network for SAR image despeckling." Remote Sensing 10, no. 2 (2018): 196.

[5] Chierchia, G., El Gheche, M., Scarpa, G., & Verdoliva, L. (2017). Multitemporal SAR im- age despeckling based on block-matching and collaborative filtering. IEEE Transactions on Geoscience and Remote Sensing, 55(10), 5467-5480.

[6] Mastriani, M., & Giraldez, A. E. (2016). Neural shrinkage for wavelet-based SAR despeckling. arXiv preprint arXiv:1608.00279.

[7] Cozzolino, D., Verdoliva, L., Scarpa, G., & Poggi, G. (2020). Nonlocal CNN SAR Image Despeckling. Remote Sensing, 12(6), 1006.

[8] Cozzolino, D., Verdoliva, L., Scarpa, G., & Poggi, G. (2019, July). Nonlocal SAR image despeckling by convolutional neural networks. In IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium (pp. 5117-5120). IEEE.

[9] Zhao, W., Deledalle, C. A., Denis, L., Maître, H., Nicolas, J. M., & Tupin, F. (2018, July). RABASAR: A fast ratio based multi-temporal SAR despeckling. In IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium (pp. 4197-4200). IEEE.

[10] Liu, S., Wu, G., Zhang, X., Zhang, K., Wang, P., & Li, Y. (2017). SAR despeckling via classification-based nonlocal and local sparse representation. Neurocomputing, 219, 174- 185.

[11] Ma, X., Shen, H., Zhao, X., & Zhang, L. (2016). SAR image despeckling by the use of variational methods with adaptive nonlocal functionals. IEEE Transactions on Geoscience and remote sensing, 54(6), 3421-3435.

[12] Chierchia, G., Cozzolino, D., Poggi, G., & Verdoliva, L. (2017, July). SAR image despeckling through convolutional neural networks. In 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 5438-5441). IEEE.

[13] Tang, X., Zhang, L., & Ding, X. (2019). SAR image despeckling with a multilayer perceptron neural network. International Journal of Digital Earth, 12(3), 354-374.

[14] Dutt, Vinayak, and James F. Greenleaf. "Adaptive speckle reduction filter for log-compressed B-scan images." IEEE Transactions on Medical Imaging 15.6 (1996): 802-813.

[15] Tyagi, T., Gupta, P., & Singh, P. (2020). A hybrid multi-focus image fusion technique using SWT and PCA. Paper presented at the Proceedings of the Confluence 2020 - 10th International Conference on Cloud Computing, Data Science and Engineering, 491-497. doi:10.1109/Confluence47617.2020.9057960

DOI: 10.54254/2755-2721/20/20231057

[16] Singh, P., & Shree, R. (2016). Speckle noise: Modelling and implementation. International Journal of Control Theory and Applications, 9(17), 8717-8727

[17] Wadhwa, P., Aishwarya, Tripathi, A., Singh, P., Diwakar, M., & Kumar, N. (2020). Predicting the time period of extension of lockdown due to increase in rate of COVID-19 cases in india using machine learning. Materials Today: Proceedings, 37(Part 2), 2617-2622. doi:10.1016/j.matpr.2020.08.509

[18] Lattari, F., Gonzalez Leon, B., Asaro, F., Rucci, A., Prati, C., & Matteucci, M. (2019). Deep learning for SAR image despeckling. Remote Sensing, 11(13), 1532.

[19] Vitale, S., Cozzolino, D., Scarpa, G., Verdoliva, L., & Poggi, G. (2019). Guided patchwise nonlocal SAR despeckling. IEEE Transactions on Geoscience and Remote Sensing, 57(9), 6484-6498