March - April2020
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A Comparative Analysis on SAR Image Despeckling Techniques

Prabhishek Singh[1], Amrendra Tripathi[2], Shilpi Singh[3], Manoj Diwakar[4]*, Raj Shree[5]

[1]Department of CSE, Amity School of Engineering and Technology, Amity University Uttar Pradesh, Noida, India Email: prabhisheksingh88@gmail.com

[2]University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India, Email: tripathiamrendra@gmail.com

[3]Department of CSE, Amity School of Engineering and Technology, Amity University Patna, India, Email: shilpi.singh.it@gmail.com

[4]Department of CSE, Graphic Era (Deemed to be University) Dehradun, Uttarakhand, India, Email: manoj.diwakar@gmail.com

[5]PI (CSTUP), Department of IT, Babasaheb Bhimrao Ambedkar University, Central University, Lucknow, India, Email: rajshree.bbau2009@gmail.com

*Corresponding Author

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Abstract:
The speckle noise is inherently generated in the SAR image during the phase of image acquisition/ capture. It has bad impact on the SAR image. The SAR image holds lot of useful information due to its various major applications like climate monitoring, agricultural land and forestry monitoring, and many more. If the quality of the SAR image is good then much useful information can be retrieved from it but if the quality is not good then there is problem in extracting out necessary information. The quality factor is highly dependent on the presence of speckle noise in the SAR image. Therefore the pre-processing step i.e. SAR image despeckling is a mandatory step in the generation of the SAR image. This paper describes some of the conventional and non-conventional SAR image despeckling methods and compares them on the basis of two factors i.e. qualitative and quantitative measures.

Keywords: *SAR image despeckling, speckle noise, homomorphic methods, non-homomorphic methods.*

I. INTRODUCTION

RAdio **D**etection **A**nd **R**anging is abbreviated as RADAR. RADAR is used to define the range, angle, or velocity of entities using high frequency electromagnetic radiations i.e. radio waves. There are two types of RADAR i.e. RAR and SAR. The satellite images are captured using these radars. The RAR i.e. Real Aperture Radar captures the high resolution satellite images of limited resolution. The resolution is limited due to the fixed antenna length [13]. Due to this issue, the RAR is unable to capture large terrain of the earth surface. This problematic issue is resolved by the SAR i.e. Synthetic Aperture Radar. SAR is kind of radar that uses high frequency electromagnetic radio waves to capture the high resolution images of the large area of the earth surface. The SAR antenna mounted on the aircraft is attached synthetically due to which it is movable and capable of

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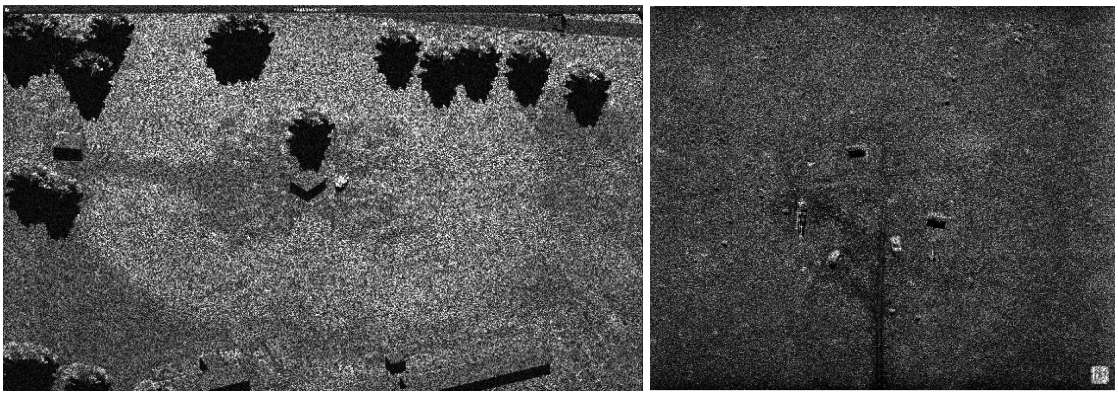
capturing large area of the earth surface. The SAR antenna moves as the aircraft moves [12].

The SAR consistently emits the high frequency electromagnetic radiations i.e. radio waves on the objects of the earth surface. These electromagnetic radiations hit the target on the earth surface and reflect back to the antenna of the SAR. The interaction of electromagnetic radiations with the target is of two types i.e. constructive and destructive [18]. When electromagnetic radiations hit the target and if most of the energy is reflected back to antenna then this interference is constructive and if very less or no energy is reflected back to the antenna then this interference is destructive. The constructive and destructive interference depends on the surface of the target object. The bright area of the SAR image shows the constructive interference and the dark area of the SAR image shows the destructive interference. This process is inherent in SAR image creation. The constructive and destructive interference generates a granular pattern scattering phenomenon. This granular pattern scattering phenomenon is called as the speckle noise. This noise distorts the image quality and disturbs the information of the SAR image. The speckle noise inherently exists in the SAR image. The Figure 1(a) and (b) shows the speckled SAR image with noise variance (σ) = 20.



(a) (b)

Figure 1. Speckled SAR images

The bright and dark patches shown in the Figure 1 depicts the constructive and destructive interference i.e. speckle noise [15]. Since the speckle noise remains in the SAR image from the beginning stage i.e. creation stage. Therefore it is mandatory to deal with this issue. Hence a preprocessing step is introduced to handle this issue i.e. SAR image despeckling. This method removes/ reduces the speckle noise in the SAR image so that maximum information can be retrieved from the SAR image [14].

The paper discusses various conventional and non- conventional techniques for SAR image despeckling and compares them on the basis various qualitative and quantitative measures. This paper is divided into four sections. The section I introduces the concept of SAR image and speckle noise. Section II briefly discusses the various SAR image despeckling methods. Section III discusses the various experimental results and its qualitative and quantitative performance of the methods and section IV concludes the article.

II. Literature Survey

The SAR image despeckling methods are divided into two groups i.e. Bayesian and non-

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March - April2020
ISSN: 0193-4120 Page No. 5978 - 5985

Bayesian approach. The Bayesian approach based methods are further divided into two groups i.e. spatial and transform domain [16]. The Bayesian approach in spatial domain holds some of the standard despeckling methods. The major research in the field of SAR image despeckling is done in the wavelet domain i.e. homomorphic and non-homomorphic filtering. The related methods to the wavelet domain come under Bayesian approach in transform domain. These methods are highly efficient [17]. This is the highly researched area in despeckling. The non-Bayesian includes some of the highly efficient methods like anisotropic diffusion, bilateral, nonlocal filtering etc. Figure 2 shows the classification of despeckling methods.

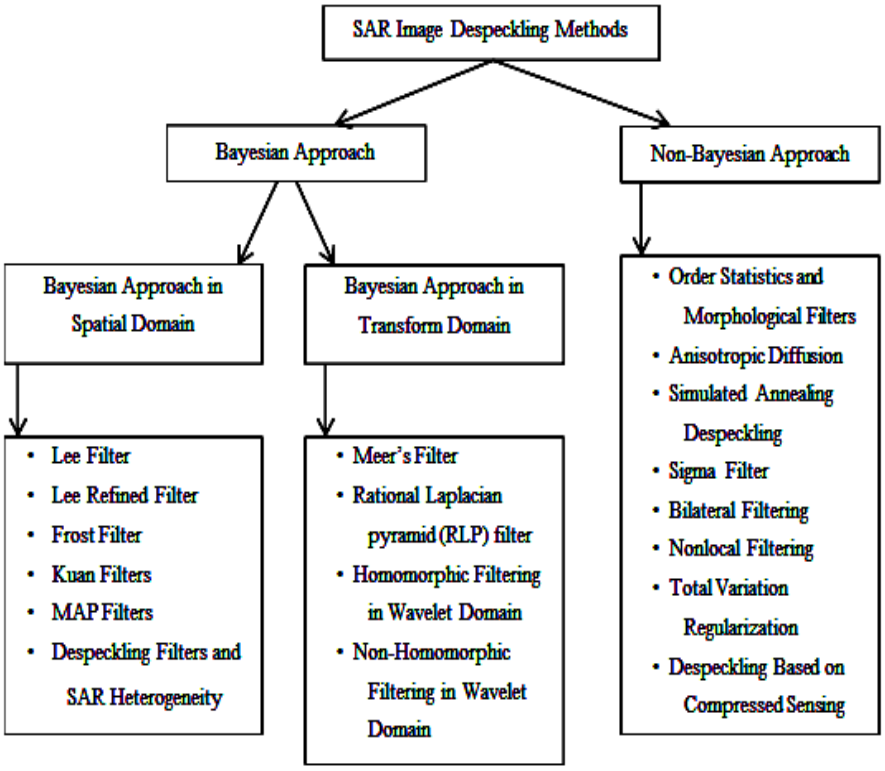

Figure 2. Classification of SAR image despeckling methods

The Frost filter [5] in 1982 is an exponentially weighted averaging filter and is adaptive in nature. An optimal MMSE filter is used for smoothing images. The speckle noise is reduced by this filter and fine details are preserved in the image. Its major demerit is blurriness in the output despeckled images. Raj Shree et al. [9] in 2018 proposed a wavelet based SAR image despeckling method using hybrid median filter. Here Bayesian - soft thresholding is applied on the high frequency components of the image and hybrid median filter is applied on the low frequency component of the image. Kuan [53] in 1985 proposed a method based on the advancement to Lee's algorithm. It is an adaptive noise smoothing filter. It is adapted to local changes in image statistics based on a non-stationary mean, non-stationary variance image model. This filter can deal with various noises which depend on signal characteristics. Kuwahara filter [8] is an adaptive speckle noise reduction filter used in speckled SAR image. It blurs out the edges and creates the block artifacts. However it is capable to apply smoothing in the uniform regions of the image while preserving the edges and corners. Lee JS

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[4] in 1980 used the neighborhood intensity values in the kernel. All the pixels are processed separately. During the movement of kernel, the local statistics of the pixels within the kernel are taken into consideration. P. Perona and J. Malik [7] in 1990 introduced a concept of anisotropic diffusion and proposed a new description of scale-space, and a category of procedures used to understand a diffusion method is familiarized. The main motive of this technique was to reduce the image noise and preserving of the fine details of the image especially edges, lines and other details which are necessary for the understanding of the image.

Table 1. Summary of despeckling methods

Despeckling methods	Advantages	Disadvantages
Frost filter [5]	Smoothens the homogeneous areas, preserves edge structure, computationally efficient, effective in spatial domain.	Ineffective in frequency domain.
Hybrid median filter [9]	Better corner and edge preserving characteristics.	Over smoothing over high textured images.
Kuan filter [6]	Deals with various types of signal-dependent noise, no a priori information about the original image are required, Simple structure of algorithm.	Introduction of artifacts and high computational cost.
Kuwahara filter [8]	Effectively reduce speckle noise.	Create block artifacts.
Lee filter [4]	Minimizes the MSE and preserve relatively sharp edges.	Over smoothing over homogeneous areas.
SRAD [7]	Efficient speckle reduction in in homogeneous regions, better despeckling performance and edge preservation capability.	High computational cost.

III. Experimental Results and Discussion

The experimental testing is performed on following despeckling methods i.e. Frost filter [5], Hybrid median filter [9], Kuan filter [6], Kuwahara filter [8], Lee filter [4] and SRAD [7]. The testing is performed on SAR dataset available at open public access database i.e. http://www.sandia.gov/RADAR/imagery/.

Figure 3 – 8 shows the comparative qualitative analysis of the despeckling methods. The quantitative analysis of all despeckling methods is performed using various parameters i.e. Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Structural Similarity Index Metric (SSIM) as shown in the Table 2 - 4.

There are certain factors depending on which the qualitative analysis is performed. Those are existence of blocking artifacts, speckle noise reduction, edge and corner preservation, smoothness in uniform regions and texture preservation in the non-uniform regions. As per these factors, the visual analysis is performed on the despeckling results of all compared methods. On zooming the image, quality can be analyzed. The smoothness in the uniform regions of SRAD method is well and more preserved as compare to others. Few artifacts are generated in the

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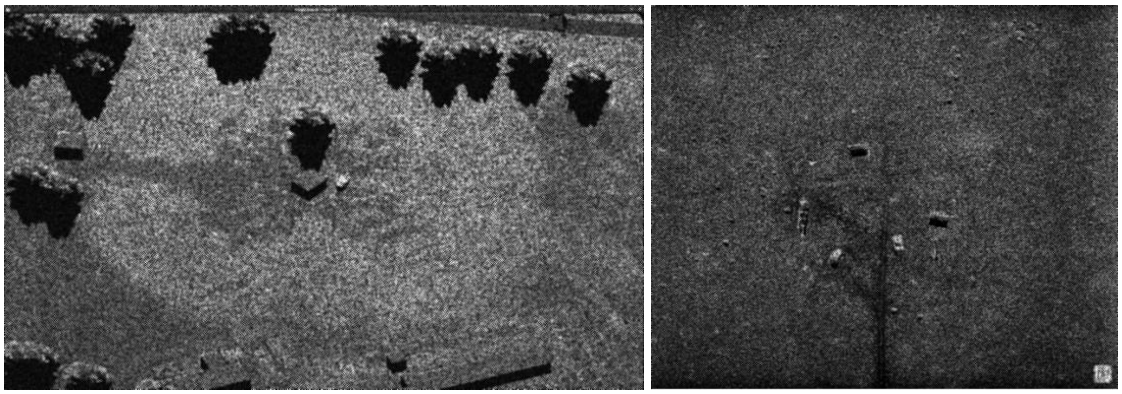
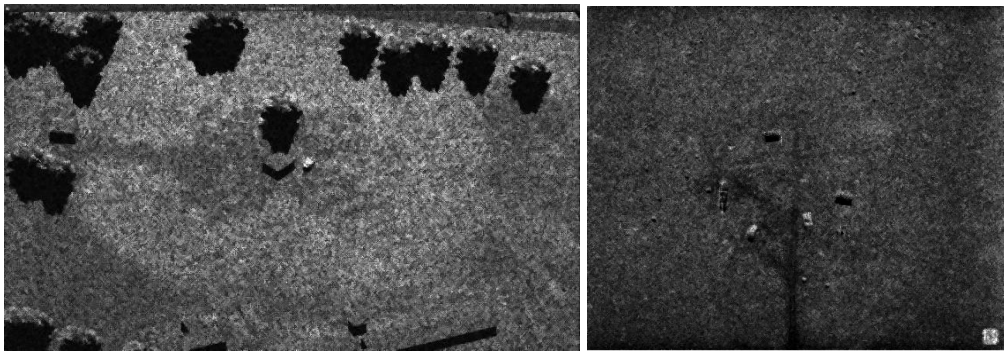
results of the Kuwahara filter during the despeckling process. The Kuan filter shows the better speckle reduction than others. The edge and texture preservation in the SRAD results are better than others. The Hybrid median filter shows overall good image quality. The results of SRAD method show the best visual quality



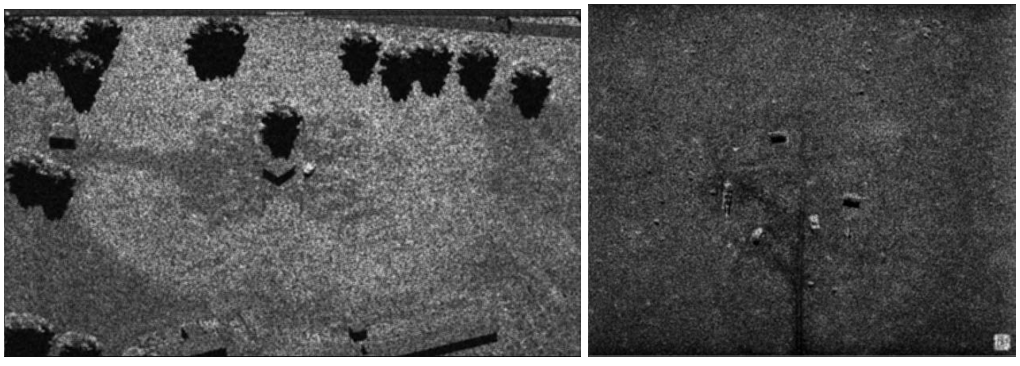
(a) (b)

Figure 3. Frost filter



(a) (b)

Figure 4. Hybrid median filter



(a) (b)

Figure 5. Kuan filter

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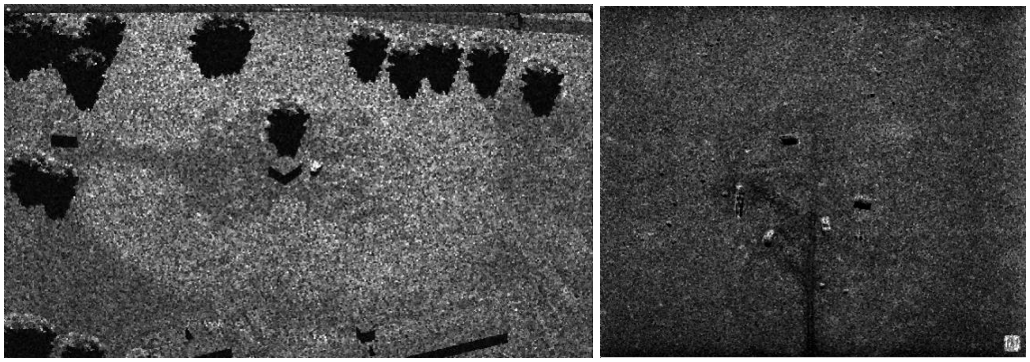
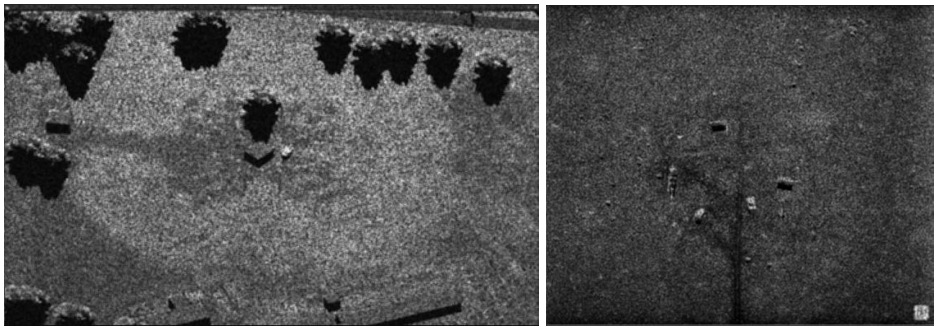
ISSN: 0193-4120 Page No. 5978 - 5985



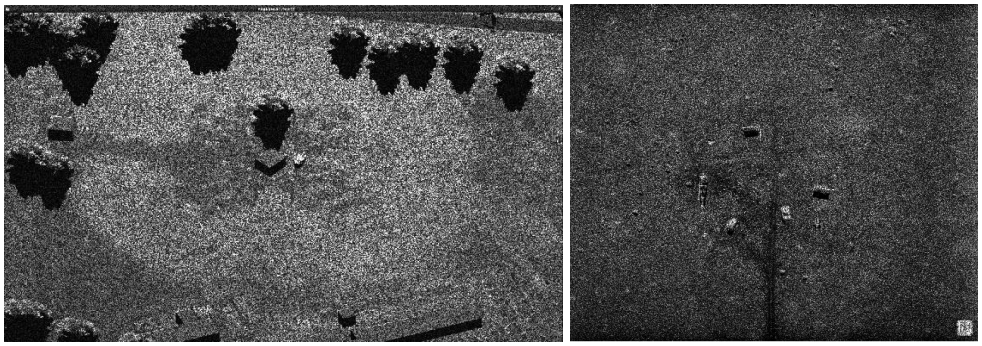
(a) (b)

Figure 6. Kuwahara filter



(a) (b)

Figure 7. Lee filter



(a) (b)

Figure 8. SRAD

Table 2 shows the quantitative results of all methods on the basis of PSNR. SRAD method produces the highest PSNR values which represents the best overall performance. Lee and Hybrid median filter also shows high PSNR values. As per Table 3, SRAD shows small MSE values but Lee and Hybrid median filter generates smaller MSE values than the SRAD. Kuan and Kuwahara filter shows high MSE values that results to low PSNR values. SSIM metric analyses the luminance, contrast and structure (edge) of the despeckled image. On the basis of these metrics, SRAD shows the best preservation of edges and texture. Since the SAR images are low contrast images, therefore special care is needed while despeckling process for contrast preservation. The Lee and Hybrid median filter also depicts high SSIM values.

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March - April2020
ISSN: 0193-4120 Page No. 5978 - 5985

Table 2. PSNR of despeckling methods

	SAR Image Figure 1 (a)	SAR Image Figure 1 (b)
Frost filter [5]	16.4699	19.5998
Hybrid median filter [9]	19.6675	21.6726
Kuan filter [6]	17.7159	19.6908
Kuwahara filter [8]	17.5640	19.8779
Lee filter [4]	21.0720	22.3597
SRAD [7]	**22.3597**	**24.5213**

Table 3. MSE of despeckling methods

	SAR Image Figure 1 (a)	SAR Image Figure 1 (b)
Frost filter [5]	2931.6843	1795.2719
Hybrid median filter [9]	1403.9679	**884.8162**
Kuan filter [6]	2200.4832	1396.4820
Kuwahara filter [8]	2278.8394	1337.5788
Lee filter [4]	**1016.4688**	1002.2791
SRAD [7]	1235.8649	1024.2812

Table 4. SSIM of despeckling methods

	SAR Image Figure 1 (a)	SAR Image Figure 1 (b)
Frost filter [5]	0.7194	0.7259
Hybrid median filter [9]	0.7909	0.8026
Kuan filter [6]	0.7598	0.7695
Kuwahara filter [8]	0.7723	0.7897
Lee filter [4]	0.8125	0.8367
SRAD [7]	**0.8268**	**0.8787**

IV. Conclusion

This paper discusses various conventional and non-conventional despeckling methods for SAR images on the basis of various parameters like qualitative and quantitative analysis. Various merits and demerits are also discussed in the paper. The SRAD method shows the best despeckling performance among all compared methods. The methods are compared on the basis of visual appearance and various other metrics like PSNR, MSE and SSIM. The Lee and Hybrid median filter also shows the satisfactory despeckling results.

References

[1] J.-S. Lee, “Digital image enhancement and noise filtering by use of local statistics,” IEEE Trans. Pattern Anal. Mach. Intell., vol. PAMI-2, no. 2, pp. 165–168, Feb. 1980.

[2] J.-S. Lee, “Speckle analysis and smoothing of synthetic aperture radar images,” Comput. Graph. Image Process., vol. 17, no. 1, pp. 24–32, Sept. 1981.

[3] J.-S. Lee, “Speckle suppression and analysis for synthetic aperture radar images,” Opt. Eng., vol. 25, no. 5, pp. 636–643, May 1986.

[4] J.-S. Lee, “Refined filtering of image noise using local statistics,” Comput. Graph. Image Process., vol. 15, no. 2, pp. 380–389, Apr. 1981.

[5] V.S.Frost et al, “A model for radar images and its application to adaptive digital filtering of multiplicative noise”, IEEE Trans. Pattern Anal. And Machine Intell.,vol. PAMI-4, pp.157-166. 1982.

[6] Kuan DT, Sawchuk AA, Strand TC, Chavel P, “Adaptive noise smoothing filter for images with signal dependent noise”, IEEE Trans Pattern Anal Mach Intell., PAMI-7(2):165–77, Mar 1985.

[7] P. Perona, J. Malik, Scale space and edge detection using anisotropic diffusion, IEEE Transactions on Image Processing 12 (8), pp-629–639, (1990).

[8] M. Kuwahara. K. Hachimura, S. Eiho, and M. Kinoshita, “Processing of RIangiocardiographic images”, in K. Preston Jr., M. Onoe (Editors) Digital Processing of Biomedical Images. New York: Plenum, 1976. p.187202

[9] Raj shree et al, “A New Wavelet Based Despeckling Using Hybrid Median Filter in Real Speckled Synthetic Aperture Radar Images”, Advanced Science, Engineering and

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March - April2020
ISSN: 0193-4120 Page No. 5978 - 5985

Medicine, Volume 10, Numbers 7-8, July 2018, pp. 788-793(6)

[10] Prabhishek Singh, Raj Shree, Speckle Noise: Modelling and Implementation, published in International Journal of Control Theory and Applications, 9(17), pp. 8717-8727 © International Science Press. (2016)

[11] Y. Yu and S. T. Acton, Speckle reducing anisotropic diffusion, IEEE Trans. Image Process., vol. 11, no. 11, pp. 1260–1270, Nov. (2002)

[12] Prabhishek Singh, Raj Shree, Statistical Modelling of Log Transformed Speckled Image, published online in Vol. 14 No. 8 AUGUST International Journal of Computer Science and Information Security, (pp. 426-431). (2016)

[13] Prabhishek Singh, Raj Shree, Statistical Quality Analysis of Wavelet Based SAR Images in Despeckling Process, Asian Journal of Electrical Sciences (AJES), Volume 6 No.2 July-December pp 1-18. (2017)

[14] Prabhishek Singh, Raj Shree, Quantitative Dual Nature Analysis of Mean Square Error in SAR Image Despeckling, in International Journal on Computer Science and Engineering (IJCSE), Volume 9 Number 11 Nov, Page: 619-622. (2017)

[15] Prabhishek Singh, Raj Shree, Analysis and Effects of Speckle Noise in SAR Images, 2nd International Conference on Advances in Computing, Communication, & Automation (ICACCA) (Fall), Pages: 1 – 5. (IEEE International Conference). (2016)

[16] Prabhishek Singh, Raj Shree, "A new homomorphic and method noise thresholding based despeckling of SAR image using anisotropic diffusion", Journal of King Saud University – Computer and Information Sciences (2017), Elsevier, http://dx.doi.org/10.1016/j.jksuci.2017.06.006.

[17] Prabhishek Singh, Raj Shree, Manoj Diwakar, "A new SAR image despeckling using correlation based fusion and method noise thresholding", Journal of King Saud University – Computer and Information Sciences (2018), Elsevier, https://doi.org/10.1016/j.jksuci.2018.03.009.

[18] Prabhishek Singh, Raj Shree, "A new SAR image despeckling using directional smoothing filter and method noise thresholding", Engineering Science and Technology, an International Journal, Elsevier, (2018), https://doi.org/10.1016/j.jestch.2018.05.009.