RESEARCH ARTICLE OPEN ACCESS

Noise Removal in SAR Images using Orthonormal Ridgelet Transform

[1]A. Ravi, [2]Dr. P.V.Naganjaneyulu, [3]Dr.M.N. Giriprasad
[1]Research Scholar, Department of ECE, JNTUH, Hyderabad, T.S, India
[2] Professor of ECE & Principal, MVR College of Engg. & Technology, A.P, India
[3]Professor of ECE & Head , JNTUA, Anantapur, A.P, India.

ABSTRACT:
Development in the field of image processing for reducing speckle noise from digital images/satellite images is a challenging task for image processing applications. Previously many algorithms were proposed to de-speckle the noise in digital images. Here in this article we are presenting experimental results on de-speckling of Synthetic Aperture RADAR (SAR) images. SAR images have wide applications in remote sensing and mapping the surfaces of all planets. SAR can also be implemented as "inverse SAR" by observing a moving target over a substantial time with a stationary antenna. Hence denoising of SAR images is an essential task for viewing the information. Here we introduce a transformation technique called “Ridgelet”, which is an extension level of wavelet. Ridgelet analysis can be done in the similar way how wavelet analysis was done in the Radon domain as it translates singularities along lines into point singularities under different frequencies. Simulation results were show cased for proving that proposed work is more reliable than compared to other de-speckling processes, and the quality of de-speckled image is measured in terms of Peak Signal to Noise Ratio and Mean Square Error.
KEYWORDS— Speckle, SAR, denoising, ridgelet, radon, PSNR, MSE.

I. INTRODUCTION

SYTHETIC APERTURE RADAR IMAGES are those taken from various satellites such as ERS, JERS and RADARSAT. ERS provides the images of sea wind, waves and ocean, ice monitoring in costal studies and land sensing with active and passive micro wave remote sensing. The principle of SAR images is RADAR (RADIO DETECTING AND RANGING).

Due to the strong coherent nature of RADAR waves, it needs the subsequent coherent processing, because this coherent nature of SAR images were corrupted by a strong noise called “speckle” [11].

As a consequence of object detection and region of interest (ROI) in SAR images, these may have a severe challenge even for an expert, while automatic algorithms devoted to the same tasks that are not just reliable enough for most of the applications. For this reason, studying of SAR images and reducing various noises and improved spatial filter techniques is increasing. Indeed, spatial filtering techniques, likes originality proposed by Donoho [2], have been readily applied to SAR images [3], to obtain good results. However, spatial filtering approaches like mean filtering or average filtering, Savitzky filtering, Median filtering, bilateral filter and Wiener filters had been suffering with loosing edges information. All the filters that have been mentioned above were good at de-speckling of SAR images but they will provide only low frequency content of an image it doesn’t preserve the high frequency information. In order to overcome this issue Non Local mean approach has been introduced. More recently, speckle reduction techniques based on the “NON-LOCAL MEANS (NLM). It is a data-driven diffusion mechanism that was introduced by Buades *et al.* in [1]. It has been proved that it’s a simple and powerful method for digital image denoising. In this, a given pixel is de-noised using a weighted average of other pixels in the (noisy) image. In particular, given a noisy image n_i and the de-noised image $\hat{d} = \widehat{d_i}$ at pixel i is computed by using the formula

$$\widehat{d_i} = \frac{\sum_j w_{ij} n_j}{\sum_j w_{ij}} \qquad (1)$$

Where w_{ij} is some weight assigned to pixel$i \wedge j$. The sum in (1) is ideally performed to whole image to denoise the noisy image. NLM at large noise levels will not give accurate results because the computation of weights of pixels will be different for some neighborhood pixels are look likes similar.

The radar platform flies along the track direction at constant velocity. For real array imaging radar, its long antenna produces a fan beam illuminating the ground below. The along track resolution is determined by the beam width while the across resolution is determined by the pulse length. The larger the antenna, the finer the detail the radar can resolve.

In SAR, forward motion of actual antenna is used to 'synthesize' a very long antenna. At each position a pulse is transmitted, the return echoes pass through the receiver and recorded in an 'echo store'. The Doppler frequency variation for each point on the ground is unique signature. SAR processing involves matching the Doppler frequency variations and demodulating by adjusting the frequency variation in the return echoes from each point on the ground. Result of this matched filter is a high-resolution image. Figure below shows the synthetic aperture length.

Speckle noise reduction in [14] uses contourlet domain under adaptive shrinkage is used and to improve the visual quality of de-speckling and cycle-spinning technique. This is a combination of multi scale geometric analysis tool with an adaptive contourlet transform.

Feature extraction through texture extraction of synthetic aperture radar images was done by using wavelet and SVM classifier is used for classification mode under region level texture features [1].

The below paper is stacked as follows II. Related work indicates the algorithmic procedure of the approach applied, III. Proposed methodology helps in learning the mathematical formulation, IV. Results displays the images and PSNR tabular values with a best proposing technique

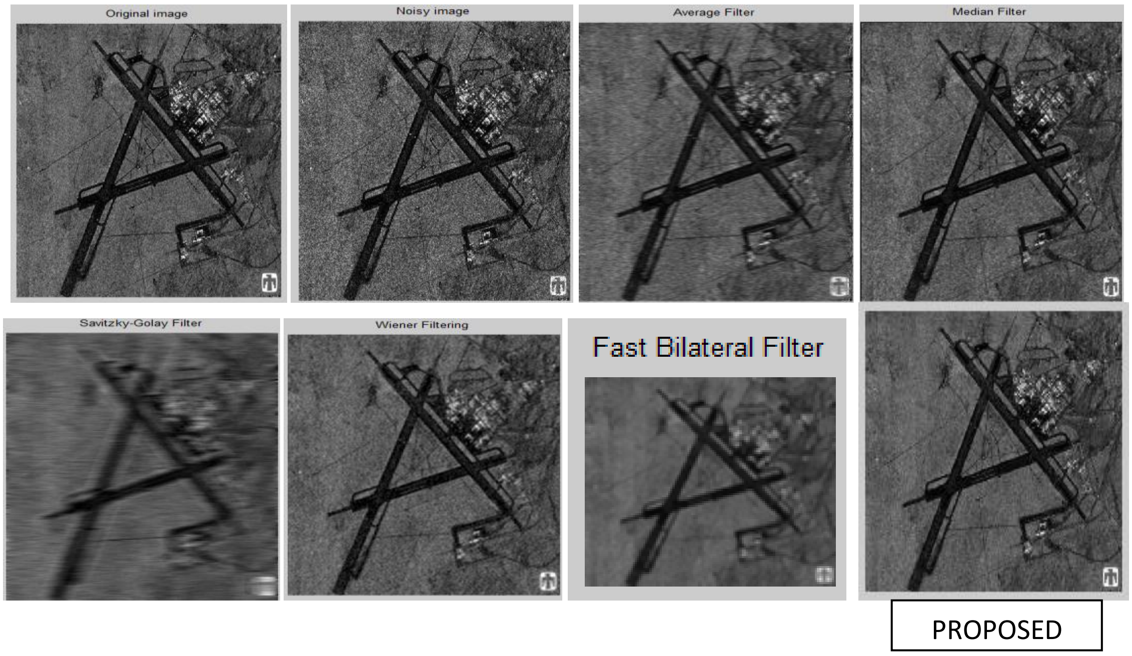

Figure 1: Comparison of proposed and conventional techniques with SAR image as input: (a) Original image (b) noisy image with sigma=20 (c) De-noise using median filter (d) using median filter (d) using savitzky-golay filter (e) using wiener filter (f) using Fast bilateral filter (FBF) and (g) Proposed.

II. RELATED WORK

Ridglelets are angular alignment information, and the length of the alignment is covered [12]. The image can be decompose and overlapping blocks of side-length pixels in a way between two vertically adjacent blocks are rectangular array of size $(b\ X\ b)/2$; we use overlap to avoid blocking artifacts and these transforms is used to build up using edge related building blocks. For an n by n image, we count $2n/b$ blocks in each direction, and thus the redundancy factor grows by a factor of 4.

An error reducing component helps in identification of improvement from the noise freed image is PSNR (peak signal noise ratio). For this purpose we are calculating Mean square error also and representing below:

$$PSNR = 20\log(MSE^2)/\max(\max(I))$$

Here we introduce a transformation technique called "Ridgelet", which is an extension level of wavelet. Ridgelet analysis can be done in the similar way how wavelet analysis was done in the Radon domain as it translates singularities along lines into point singularities under different frequencies. Simulation results were show cased for proving that proposed work is more reliable than compared to other de-speckling processes, and the quality of de-speckled image is measured in terms of Peak Signal to Noise Ratio and Mean Square Error.

Algorithm 1: DISCRETE RIDGELET TRANSFORM.

Require: Input $N \times N$ image $f\ [i1, i2]$.
STEP 1: Apply the isotropic wavelet transform 2D with J scales,
STEP 2:$B1 = Bmin$,
STEP 3: for $j = 1, \ldots, N$ do
STEP 4: Partition the sub-band W_j with a block size B_j and apply the DRT to each block,
STEP 5: if j |2| = 1 then
STEP 6: $Bj + 1 = 2Bj$,
STEP 7: else
STEP 8: $Bj + 1 = Bj$.
STEP 9: end if
STEP 10: end for

I. PROPOSED METHODOLOGY

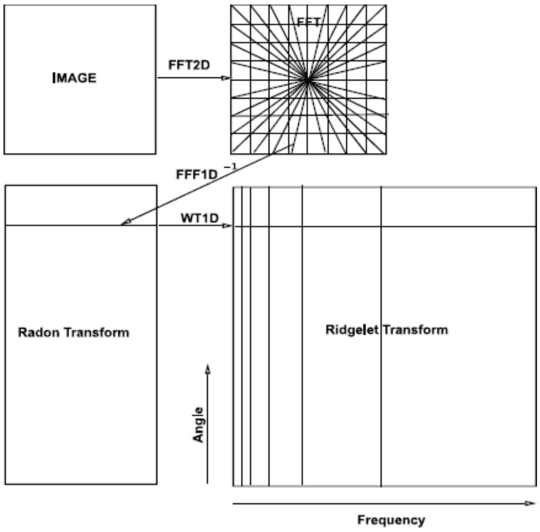

Figure 2: Discrete ridgelet transform flowchart of an image ($N \times N$).

Each of the $2N$ radial lines in the Fourier domain is processed separately. The 1-D inverse FFT is calculated along each radial line, followed by a 1-D non-orthogonal wavelet transform. In practice, the 1-D wavelet coefficients are directly calculated in the Fourier domain.

R^2 is given in [11]. If a Smooth univariate function ψ: R → R is taken with sufficient decay and also satisfy the admissibility condition given by Eq. (1) [12]

$$\int \frac{|\psi|^2}{|\xi|^2} d\xi < \infty \quad (3)$$

Then, ψ has a vanishing mean $\int \psi(t)dt = 0$ and a special normalization about $\psi$is chosen so that $\int_0^\infty |\psi(\xi)|^2 \xi^{-2} d\xi = 1$

For each scale (a) > 0, each position (b) $\in R$and each orientation$(\theta) \in [0, 2\pi)$, the bivariate Ridgelet $\psi_{a,b,\theta}$ is defined as [11, 12]

$$\psi_{a,b,\theta}(x) = a^{-1/2}\psi\,(x_1 cos\theta + x_2 sin\theta - b)/a \quad (4)$$

A Ridgelet is constant along lines $x_1 cos\theta + x_2 sin\theta = const.$ These ridges are transverse, it becomes a wavelet. Given an integral function f(x), Ridgelet coefficients are defined as [12]

$$R_f(a, b, \theta) = \int \psi_{a,b,\theta}(x)\, f(x) dx \quad (5)$$

And the extract reconstruction is obtained by using the above equation is

$$f(x) = \int_o^{2\pi} \int_{-\infty}^{\infty} \int_0^{\infty} R_f(a, b, \theta)\, \psi_{a,b,\theta}(x) \frac{da}{a^3} db \frac{d\theta}{4\pi} \quad (6)$$

Ridgelet analysis can also be done similar to wavelet analysis in the Radon domain as it translates singularities along lines into point singularities, for which the wavelet transform is known to provide a sparse representation [6].

Radon transform of an object f is defined as the collection of lines integral indexed by$(\theta, t)\varepsilon[0, 2\pi) \times R$:

$$Rf(\theta, t) = \int f(x_1, x_2) \partial(x_1 cos\theta + x_2 sin\theta - tdx1dx2 \quad (7)$$

In eq.7 '∂' is the Dirac distribution. It means that the Ridgelet transform is the application of 1D-DWT for the slices of Radon transformation and the angular variable $'\theta'$ is remained as constant and 't' contains varying nature [12]. Therefore, for computing continuous Ridgelet transform, initially Radon +transform is determined, then 1-D wavelet transform is applied to the slices. A detailed discussion on Ridgelet transforms is given in [11, 12] and the reference therein.

From literature review, it is found that Ridgelet transform is optimizing for finding the lines only with size of the image and for detecting line segments; the concept of partitioning was introduced [13] & [12]. If a 2D signal having n by n size, then 2n/b such blocks in each direction is counted. The authors in [12] presented the two competing strategies which perform the analysis and their synthesis [12]. In first method, the blocks and their values were analyzed in such that the original pixel was constructed from the co-addition of all blocks. While in second method, only those block values are analyzed when the signal is reconstructed (synthesis) [11, 12]. From different experiment, the authors in [12] have concluded that the second approach yields improved performance. From second method, a pixel value, $f(i,j)$ by its four corresponding blocks and their values of half size $l = b/2$, namely, $B_1 = (i_1, j_1)$, $B_2 = (i_1, j_1)$, $B_3 = (i_2, j_2)$ and $B_4 = (i_2, j_2)$ with $i_1, j_1 > b/2$ and $i_2 = i_1 - l, j_2 = j_1 - l$ is computed as [12]:

$$f_1 = \omega\left(\frac{i_2}{l}\right) B_1(i_1, j_1) + \omega(1 - i_1/l) B_2(i_1, j_1) \quad (8)$$

$$f_2 = \omega\left(\frac{i_2}{l}\right) B_3(i_1, j_2) + \omega(1 - i_2/l) B_4(i_2, j_2) \quad (9)$$

$$f(i,j) = \omega(j_2/l) f_1 + \omega(1 - j_2/l) f_2 \quad (10)$$

In above equations, $\omega(x) = cos(\pi x/2)^2$. Detailed discussion on Ridgelet transform is given in [11-13] and the reference therein.

Filtration process is followed by a mask approach which uses the function from MATLAB visionary tool box. They are fspecial and imfilter.

Fspecial helps in creating the mask of an image where imfilter will helps in applying the mask to the image and tries to reduce the noise in the image and can be analyzed by using error calculating parameters. They might lmse, mse, RMSE, PSNR, bit error rate. For similarity measure we can also access SSIM, cross correlation e.t.c.,

Figure 2 illustrates various filtration and transformation techniques for obtaining the best PSNR from a noised image. These results were also showcased in table 1. While observing the output of the image noticed that for savizky-golay filter even when there is a best value of PSNR still a blur is appearing in the image and quietly observed in other images so the reconstruction of the image is a little bit of conditioned value so, to improve this mode transformation mode is activated by NLM wavelet process and reconstruction is made possible with ease this also helps in achieving the best value of PSNR.

Algorithmic procedure followed for reduction of noise:

Input: Consider NXN Image for speckle noise reduction.
Output: Speckle noise reduced.
Step1: Consider an NXN image for noise reduction.
Step2: Applying Speckle noise to the image.
Step3: Applying various filtration approaches:
- Step I: Average filtering
- Step II: Median Filtering
- Step III: Savitzky- Golay filtering
- Step IV: NLM Filter
- Step V: Bilateral Filter
- Step VI: Wavelet TRANSFORM
- Step VII: RIDGELET TRANFORM

$$f(x) = \int_o^{2\pi} \int_{-\infty}^{\infty} \int_0^{\infty} R_f(a,b,\theta)\, \psi_{a,b,\theta}(x) \frac{da}{a^3} db \frac{d\theta}{4\pi}$$

Step4: Calculating MSE.
Step5: Calculating PSNR.

IV. RESULTS

To demonstrate the performance of proposed algorithm, various SAR images of size 256x256 and 512x512 were corrupted by speckle noise and by varying the standard deviation sigma = 0.1 to 10. This corrupted image has been de-noised by using mean filter, median filter, Savitzky- golay filter, NLM filter, Bilateral filter and wavelet filtering. The results which were shown in fig.3, helps in identifying that the proposed ridgelet technique is significantly, comparatively effective than the other techniques in terms of visual perceptual quality. Tabular values and the graphs help in identifying the PSNR values and the change of error from the images with low blurring and loss of information. So, in further advance level SSIM, LMSE, RMSE and other parameters will also calculable for identifying the most advancement error reduction approach.

Figure 3 helps in visualizing the outputs of various filtration approaches and noise free output from average filter, median filter, savitzky-golay filter, wiener filter, fast bilateral filter. This illustrates various filtration and transformation techniques for obtaining the best PSNR from a noised image. These results were also showcased in table 1.

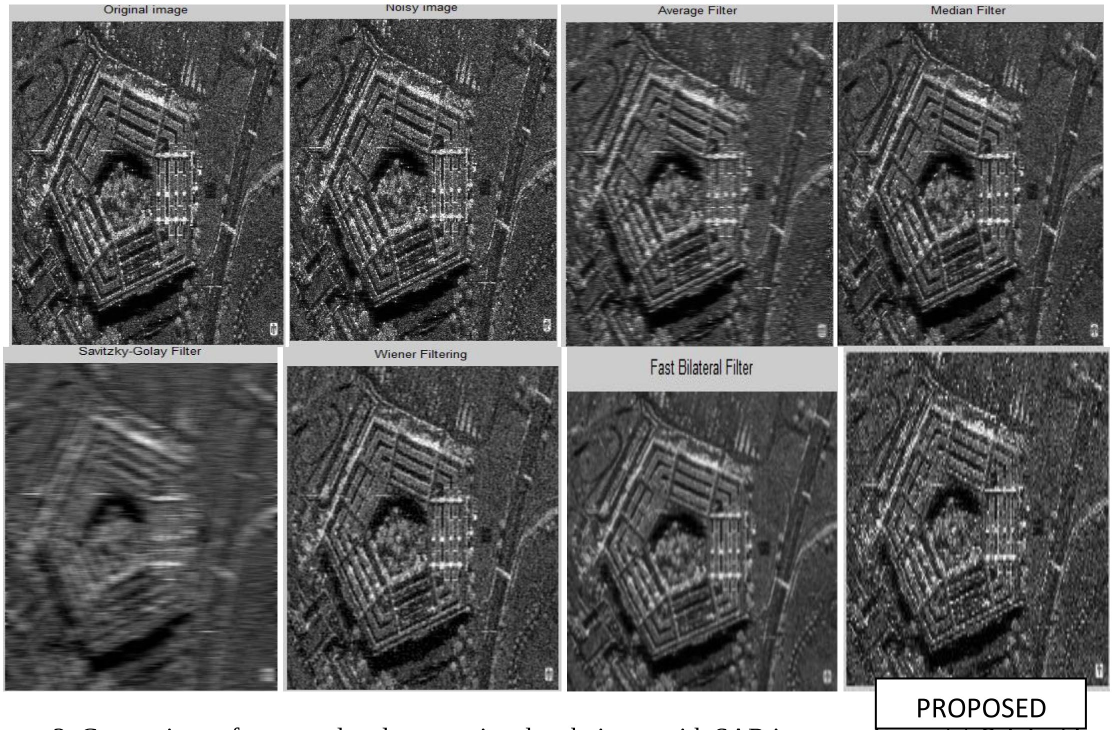

Figure 3: Comparison of proposed and conventional techniques with SAR image as input: (a) Original image (b) noisy image with sigma=20 (c) De-noise using median filter (d) using median filter (d) using savitzky-golay filter (e) using wiener filter (f) using Fast bilateral filter (FBF) and (g) Proposed.

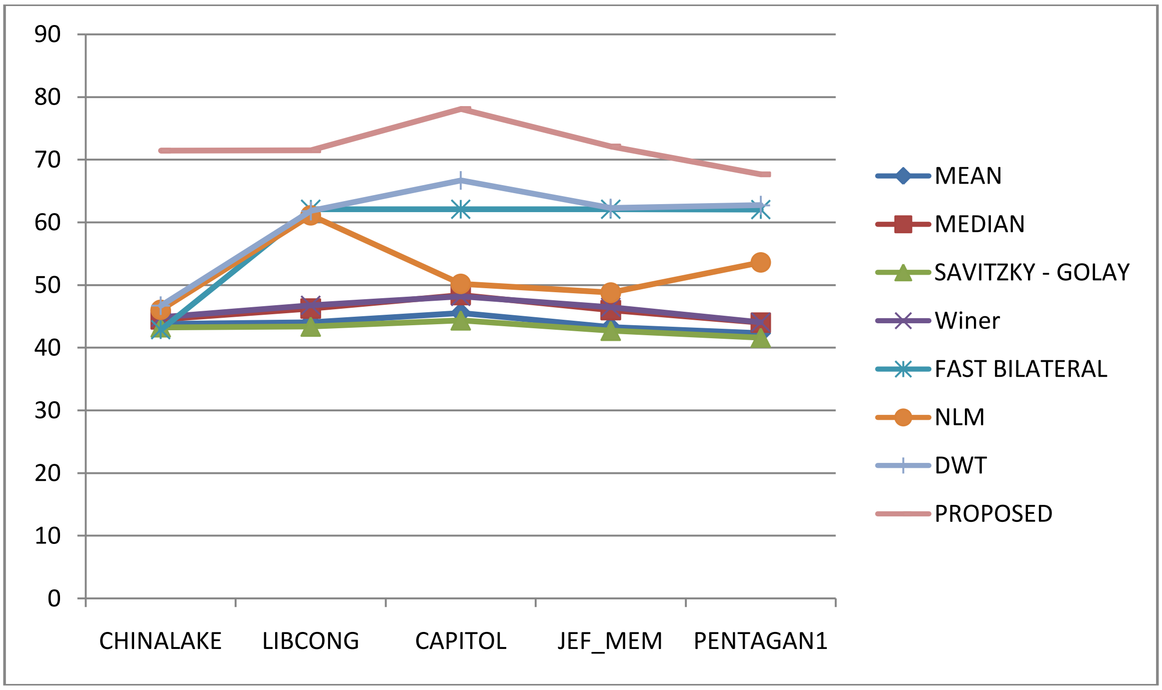

Figure 4: Quality analysis of proposed and conventional techniques in terms of PSNR.

Table 1: SNR values of various image under different filtration approaches.

TECHNIQUE	**IMAGES AND SNR**				
Filtering / Transformation Technique	**CHINALAKE**	**LIBCONG**	**CAPITOL**	**jef_mem**	**pentagan1**
MEAN	43.836	44.09	45.5513	43.2944	42.333
MEDIAN	44.5403	46.2522	48.3741	46	44.0085
Savitzky-Golay	43.2603	43.3747	44.3741	42.7	41.5899
Wiener	44.879	46.782	48.2	46.46	44.0356
Fast Bilateral	42.8604	62.0542	62.0753	62.079	62.038
NLM	46.05	61.1276	50.1738	48.785	53.6242
DWT	46.719	61.8056	66.6804	62.28	62.7268
Ridgelet(PROPOSED)	**71.437**	**71.45**	**78.0683**	**72.095**	**67.6421**

The quality analysis have made and plotted in the figure 3. These were also calculated and tabulated the results for comparison of various techniques. These tabulated results were tabulated in table 1.

Fig.1 and Fig.3 indicating various approaches or filtration technique on two different images and by all Verification approaches such PSNR value calculation and proves the proposed ridgelet transform plays the best role in removing the speckle noise. A high change in the PSNR values from different filtration techniques with different transformation approaches provides best results for the image set considered.

CONCLUSION

In this paper, Ridgelet transformation used for reducing the noise for reconstruction of image and speckle noise distribution modeling the sub-band coefficients. The image de-noising algorithm uses soft and hard thresholding to provide smoothness and better image details preservation. The Ridgelet de-noise algorithm produces overall better PSNR results compared with other traditional de-noises approaches. Table 1 and Fig. 4 represents various images were testing under different filtration approaches and proving Ridgelet transform is the best in reducing speckle noise from images. Fig. 4 is useful to explain various PSNR for various image and their comparison in proving Proposing Ridgelet approach provides best PSNR and helps in reducing the noise. As a future enhancement image segmentation and identifying the back ground with the proposed filtration techniques.

ACKNOWLEDGEMENTS

Heartful thanks to Dr. P. V. Naganjeneyulu and Dr. Giri prasad for their consistent support and guidance by providing necessary SAR images helps in completion of this paper.

REFERENCES

[1] Akbarizadeh, G. “A New Stastical Based Kurtosis Wavelet Energy Feature for Texture Recognition of SAR Images”, volume 50, Page(s) 4358-4368

[2] Baselice, F Ferraioli,G.”Unsupervised Coastal Line Extraction Form SAR Images” Volume:10, Page(s):1350-1354.

[3] Deledalle, C.A ;Denis,L ; Poggi, G ; Tupin, F ; Verdoliva. L.“Exploting Patch Similarity for SAR Images Processing: The nonlocal Paradigm”, Volume: 31, Publication Year: 2014 , Page(s): 69 - 78

[4] Doring, B.J ; Schwerdt, M. “The Radiometric Measurement Quantity for SAR Images”, Volume: 51 Publication Year: 2013 , Page(s): 5307 – 5314

[5] Maslikowski, L samczynski, P ; Baczyk, M ; Krysik, P ; Kulpa, K. “Passive bistatic SAR imaging — Challenges and limitations”, Volume: 29, Publication Year: 2014 , Page(s): 23 – 29.

[6] Xingyu Fu ; Hongjian You ; Kun Fu “A statistical Approach to Detect Edges in SAR Images based on Square successive Difference of Averages” Volume: 9, Publication Year: 2012 , Page(s): 1094 - 1098 .

[7] Deliaing Xiang ; Tao Tang ; Canbin Hu ; Yu Li ; Yi Su “A Kernel Clustering Algorithm With Fuzzy Factor: Application to SAR Images Segmentation” Volume; 11 Publication Year: 2014, Page(s): 1290-1294.

[8] Maarten Jansen, “Noise Reduction by Wavelet Thresholding”, Springer Verlag New York Inc. 2001.

[9] D.L. Donoho and I.M. Johnstone, ‘Ideal spatial adaptation via wavelet shrinkage’, Biometrica, Vol. 81, pp. 425-455,1994.

[10] D.L. Donoho and I.M. Johnstone, “Wavelet shrinkage: Asymptopia”, J.R. Stat. Soc. B, ser. B, Vol. 57, no. 2, pp. 111-369, 1995.
[11] J. L. Starck, D.L Donoho, E.J Candes, “Astronomical image representation by the curvelet transform” Aastronomy and astrophysics (berlin print), Vol. 398, pp.785-800, 2003.
[12] M.J. Fadili , and J.-L. Starck, “Curvelets and Ridgelets”, Technical report, 2007.
[13] Shiyon Cui, Dumitru, Datcu. M, “radio Detector Based feature extraction for very high resolution SAR Image Patch Indexing”,
[14] J. S. Lee "Speckle Suppression and Analysis for Synthetic Aperture Radar Images", *Optical Engineering*, vol. 25, no. 5, pp.636 - 645 1986

AUTHOR BIOGRAPHY

A. Ravi received his Bachelors degree in ECE from JNT University, and received his M.Tech from JNTU Kakinada. He is now a Research scholar in JNTUH Hyderabad, under the guidance of **Dr. P.V. Naganjaneyulu & Dr. M.N. Giriprasad**. His current research interest includes Satellite and SAR image processing.

Dr. P.V. Naganjaneyulu received Ph. D in Communications from JNTU Kakinada University. And he is currently professor and Principal, Department of ECE in M.V.R College of Engineering & Technology, Paritala, Krishna District.A.P, he was specialized in communication and signal processing, he published 50 journal papers and 10 conference papers. His current research area of interest is communications, signal processing and image processing. He is a member of IETE.

Dr. M.N. Giriprasad Received the B.Tech degree from JNTUA, Andra Pradesh, M.Tech from SVU, Tirupathi and Ph.D. from JNTUH. He is now working as Professor of ECE & Head JNTUA at JNTU College of engineering Ananthapur, A.P. His current research interests include Wireless communications, Bio medical Instrumentation and image processing. He is a member of ISTE, IE & NAFE.