Wavelet Based Image Denoising Using Ant Colony Optimization Technique for Identifying Ice Classes in SAR Imagery

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Abstract. Interpretation of satellite radar images is an important ongoing research field in monitoring river ice for both scientific and operational communities. This research focus on the development of optimal recognition strategies for the purpose of identifying different ice classes in SAR imagery. However acquisitions of SAR images produce certain problems. SAR images contain speckle noise which is based on multiplicative noise or rayleigh noise. Speckle noise is the result of two phenomenons, first phenomenon is the coherent summation of the backscattered signals and other is the random interference of electromagnetic signals. This therefore degrades the appearance and quality of the captured images. Ultimately it reduces the performance of important techniques of image processing such as detection, segmentation, enhancement and classification etc. This research contributes the major objectives towards speckle filtering using wavelet techniques optimized by Ant Colony Optimization (ACO). First is to remove noise in uniform regions. Second is to preserve and enhance edges and image features and third is to provide a good visual appearance. The work is carried out in three stages. First stage is to transform the noisy image to a new space (frequency domain). Second stage is the manipulation of coefficients. Third is to transform the resultant coefficients back to the original space (spatial domain).Results show that statistical wavelet shrinkage filters are good in speckle reduction but they also lose important feature details. Here the challenge is to find an appropriate threshold value, which is achieved using intra-scale dependency of the wavelet coefficients to estimate the signal variance only using the homogeneous local neighboring coefficients. Moreover, to determine the homogeneous local neighboring coefficients, the ACO technique is used to classify the wavelet coefficients. Experimentation is conducted on SAR images which are further used for development of optimal recognition system for ice classes.

Keywords: ACO, Wavelet, SAR images, Denoising, Thresholding, Shrinkage methods.

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1 Introduction

Automation in river ice image classification is desired to assist ice experts in extracting geophysical information from the increasing volume of images. Rivers and streams are the key elements in the terrestrial re-distribution of water. An ice cover has significant impact on rivers such as modifies ecosystem, affects microclimate, causes flooding, restricts navigation and impacts hydropower generation. Multiple research work is carried independently in satellite images to develop algorithms in remote sensing for classification of ice as they cover large areas. Less research has been done in preprocessing segment that can improve the precision of the interpretation. This paper presents a research work based on image processing techniques on the ice patterns in synthetic aperture radar (SAR) imagery for speckle denoising. Neural networks are known for their ability to solve various complex problems in image processing [10]. A biological motivation and some of the theoretical concepts of ant colony optimization algorithms are the inspiration of the work done in this paper [11].Here, analysis is done on the performance of wavelet derived from the optimization technique (ACO) based on image enhancement methods. The main advantage of wavelet analysis is that it allows the use of long time intervals where more precise low frequency information is wanted, and shorter intervals where high frequency information is sought. Hence wavelet analysis is therefore capable of revealing aspects of data that other image analysis techniques miss, such as trends, breakdown points, and discontinuities in higher derivatives and self-similarity. Wavelets are also capable of compressing or de-noising a image without appreciable degradation of the original image. A comprehensive experiment is carried out here based on the evaluation parameters and quantifiable metrics. This work evaluates the objective parameters and emphasizes the need of preprocessing using optimization technique (ACO) for texture based ice classification. This paper introduces a new approach, which incorporates the wavelet filter and ACO altogether, to achieve the goal of denoising and preserving the edges. The paper is structured as: Section 2 deals with the image enhancement framework. Section 3 comprises the SAR image denoising using Wavelet. Section 4 5 explains about denoising using wavelet shrinkage methods and states the need of optimization for threshold value in wavelet shrinkage and Section 6 the experimental results of the proposed optimization technique for wavelet denoising. The paper ends with section 7 with remarks on possible future work in this area and some conclusions.

2 Image Enhancement Framework

This is the first and lowest level operation to be done on images. The input and the output are both intensity images. The main idea with the preprocessing is to suppress information in the image that is not relevant for its purpose or the following analysis of the image. The pre-processing techniques use the fact that neighboring pixels have essentially the same brightness. There are many different pre-processing methods developed for different purposes. Interesting areas of pre-processing for this work is image filtering for noise suppression. Conservative methods based on wavelet transforms have been emerged for removing speckle noise from images. This local preprocessing speckle reduction technique is necessary prior to the processing of SAR images. Here we identify wavelet Shrinkage or thresholding as denoising method. It is well known that increasing the redundancy of wavelet transforms can significantly improve the denoising performances. Thus a thresholding is been obtained by optimization technique called ant colony optimization (ACO).

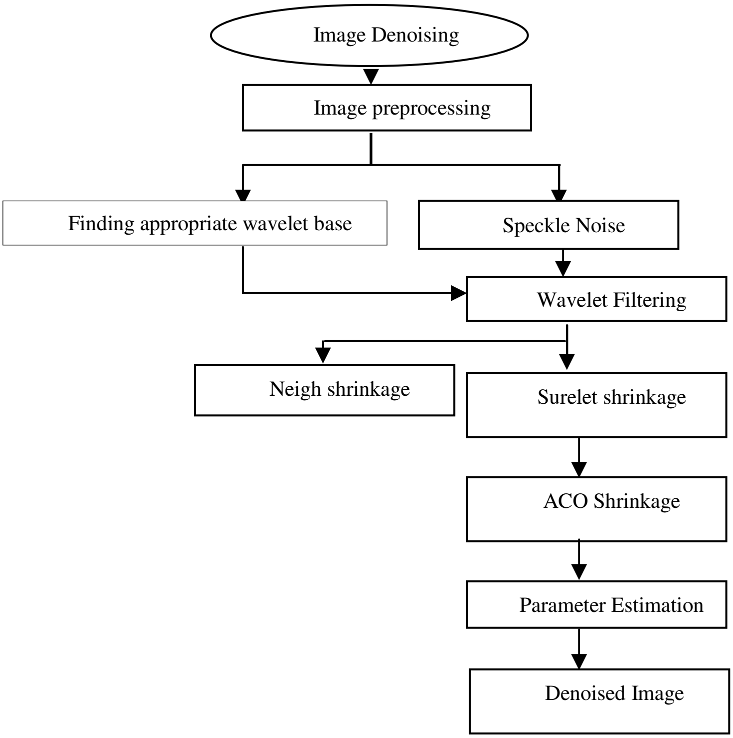

Fig. 1. Framework for Denoising SAR image for ice classification

3 SAR Image Denoising Using Wavelet

The two main confines in image accuracy are categorized as blur and noise. Blur is intrinsic to image acquisition systems, as digital images have a finite number of samples and must respect the sampling conditions. The second main image perturbation is noise. Image denoising is used to remove the additive noise while retaining as much as possible the important signal features. Currently a reasonable amount of research is done on wavelet thresholding and threshold selection for signal de-noising, because wavelet provides an appropriate basis for separating noisy signal from the image signal. Two shrinkage methods are used over here to calculate new pixel values in a local neighborhood. Shrinkage is a well known and appealing denoising technique. The use of shrinkage is known to be optimal for Gaussian white noise, provided that the sparsity on the signal's representation is enforced using a unitary transform. The main advantage of wavelet analysis is that it allows the use of long time intervals where more precise low frequency information is wanted, and shorter intervals where high frequency information is sought. Wavelet analysis is therefore capable of revealing aspects of data that other image analysis techniques miss, such as trends, breakdown points, and discontinuities in higher derivatives and self-similarity. Wavelets are also capable of compressing or de-noising a image without appreciable degradation of the original image. On the experiment evaluation Daubechies wavelet family of orthogonal wavelets is concluded as the appropriate family for shrinkage method as it is defined as a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support.

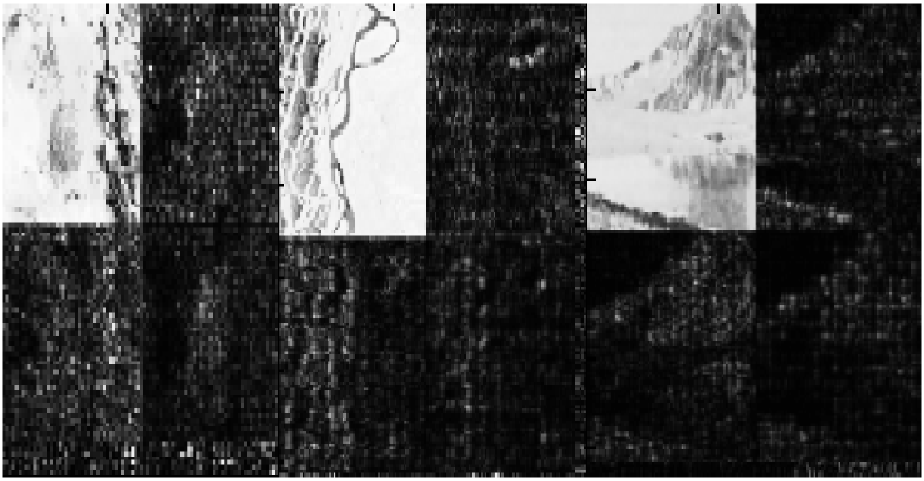

Fig. 2. Daubechies wavelet based on level 2 decomposition

4 Denoising Using Wavelet Shrinkage

Here image denoising is based on the image-domain minimization of an estimate of the mean squared error-Stein's unbiased risk estimate (SURE) is proposed and equation (1) specifies the same. Surelet the method directly parameterizes the denoising process as a sum of elementary nonlinear processes with unknown weights. Unlike most existing denoising algorithms, using the SURE makes it needless to hypothesize a statistical model for the noiseless image. A key of it is, although the (nonlinear) processing is performed in a transformed domain-typically, an undecimated discrete wavelet transform, but we also address nonorthonormal transforms-this minimization is performed in the image domain.

$$sure(t;x) = d - 2.\#\{i : |x_i| \le t\} + \sum_{i=1}^{d} (|x_i| \Lambda t)^2 \tag{1}$$

where d is the number of elements in the noisy data vector and xi are the wavelet coefficients. This procedure is smoothness-adaptive, meaning that it is suitable for denoising a wide range of functions from those that have many jumps to those that are essentially smooth. It have high characteristics as it out performs Neigh shrink method. Comparison is done over these two methods to prove the elevated need of Surelet shrinkage for the denoising the SAR images. The experimental results are projected in graph format which shows that the Surelet shrinkage minimizes the objective function the fastest, while being as cheap as neighshrink method. Measuring the amount of noise equation (2) is done by its standard deviation , , one can define the signal to noise ratio (SNR) as

$$SNR = \frac{\sigma(\mu)}{\sigma(n)}, \tag{2}$$

Where in equation (3) denotes the empirical standard deviation of

$$\sigma(\mu) = \left(\frac{1}{|I|} \sum_i (u(i) - \overline{\mu})^2 \right)^{1/2} \tag{3}$$

And is the average grey level value. The standard deviation of the noise can also be obtained as an empirical measurement or formally computed when the noise model and parameters are known.

5 Ant Colony Optimization for Wavelet Based Denoising

ACO is a nature-inspired optimization algorithm motivated by the natural collective behavior of real-world ant colonies. The key challenge of wavelet shrinkage is to find an appropriate threshold value, which is typically controlled by the signal variance. Ant colony optimization (ACO) technique is used to classify the wavelet coefficients. It exploits the intra-scale dependency of the wavelet coefficients to estimate the signal variance only using the homogeneous local neighboring coefficients.

The proposed AntShrink approach has two stages:

(i) develop the ACO technique to classify the wavelet coefficients
(ii) shrink the noisy wavelet coefficient according to a locally-adapted signal variance value.

The proposed approach is summarized as follows.

- Perform a 2-D discrete wavelet decomposition on a noisy image to get the noisy wavelet coefficients.
- Perform the ACO-based classification.
- Estimate the signal variance.
- Compute the MMSE estimation.
- Perform the inverse wavelet transform to obtain the denoised image.

The figure 3 shows the visual quality of the image after applying aco based wavelet denoising method.

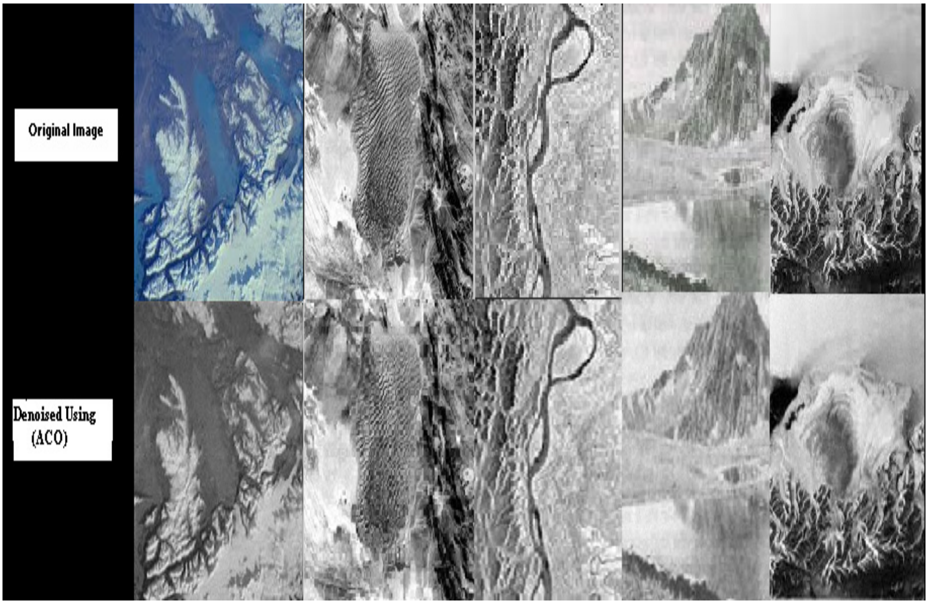

Fig. 3. Denoised image using ACO based on Db2 Wavelet Family

6 Experimental Results

Interesting areas of pre-processing for this work is image filtering for noise suppression. This local preprocessing speckle reduction technique is necessary prior to the processing of SAR images.

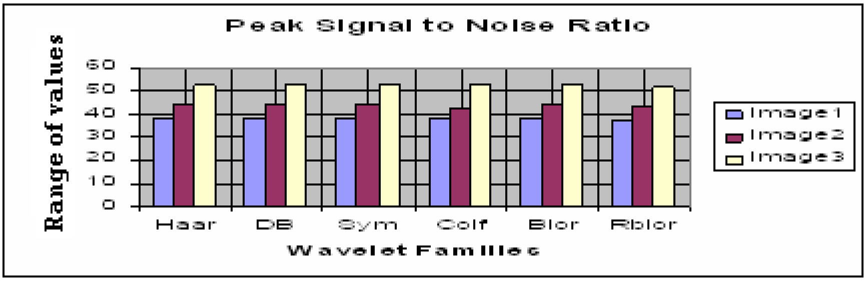

Fig. 4. Peak to Signal noise ratio for wavelet methods

Here we identify wavelet Shrinkage or thresholding as denoising method It is well known that increasing the redundancy of wavelet transforms can significantly improve the denoising performances. Thus a thresholding process which passes the coarsest approximation sub-band and attenuates the rest of the sub-bands should decrease the amount of residual noise in the overall signal after the denoising process .Figure 4,5 shows the evaluation of wavelet families to find the best and Daubechies wavelet is been concluded for wavelet shrinkage denoising.

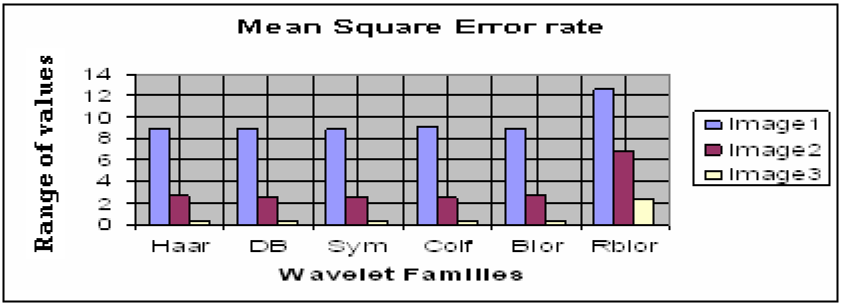

Fig. 5. Mean Square Error rate for wavelet methods

Figure 6, 7 represents the objective evaluation of the shrinkage methods and finally surelet shrinkage is been concluded as the optimal method for denoising.

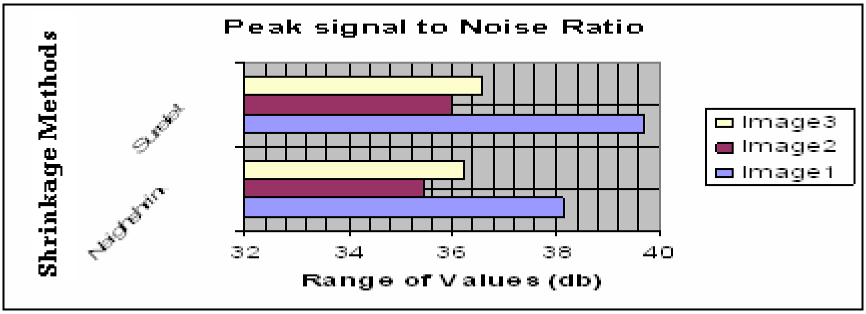

Fig. 6. PSNR values for shrinkage method based on DB Wavelet family

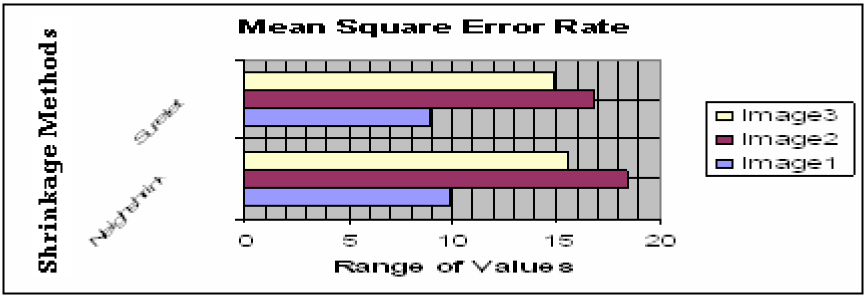

Fig. 7. MSE values for shrinkage method based on DB Wavelet family

As finally, comparison is been made between shrinkage and aco based shrinkage method for denoising SAR image.

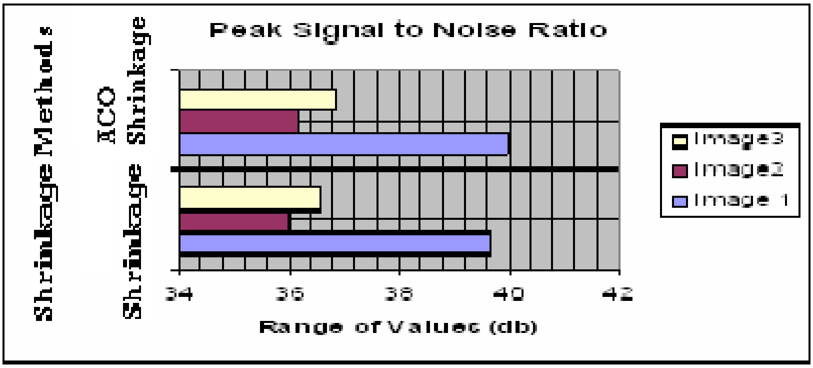

Fig. 8. Comparison of PSNR values for ACO shrinkage based on DB Wavelet family

7 Conclusion

Here an attempt is made to find a superior methodology for denoising than the conventional fixed-form neighborhoods .This methodology also determine optimal results by using finest threshold instead of using the suboptimal universal threshold in all bands. It exhibits an excellent performance for further ice detection phase and the experimental result also signifies the same by producing both higher PSNRs and enhanced visual eminence than the former and conventional methods. In future, research will be carried out to reduce the computational load of the proposed image classification algorithm and shorten the execution time of the projected approach.

References

[1] Zhang, H., Fritts, J., Goldman, S.: An Entropy-based Objective Evaluation Method for Image Segmentation. In: Storage and Retrieval Methods and Applications for Multimedia. Proceedings of the SPIE, vol. 5307, pp. 38–49 (2003)

[2] Tweed, T., Miguet, S.: Automatic detection of regions in interest in mammographies based on a combined analysis of texture and histogram. In: International Conference on Pattern Recognition, Quebec City, Canada (August 2002)

[3] Randen, T., Husoy, J.H.: Filtering for Texture Classification: A Comparative Study. IEEE Transaction on Pattern Analysis and Machine Intelligence 21(4), 291–310 (1999)

[4] Tian, J., Yub, W., Mac, L.: AntShrink: Ant colony optimization for image shrinkage. Pattern Recognition Letters 31, 1751–1758 (2010)

[5] Unser, M.: Texture Classification and Segmentation Using Wavelet Frames. IEEE Trans. on Image Processing 4(11), 1549–1560 (1995)

[6] Wang, J., Li, J., Wiederhold, G.: Simplicity: Semantics-Sensitive Integrated Matching for Picture Libraries. IEEE Transactions on Pattern Analysis and Machine Intelligence 23(9), 947–963 (2001)

[7] Liu, J., Yang, Y.-H.: Multi-resolution color Image segmentation. IEEE Transaction on Pattern Analysis and Machine Intelligence 16(7), 689–700 (1994)
[8] Chan, R.H.: An Iterative procedure for removing random- valued impulse noise. IEEE Signal Process. Lett. (11) (2004)
[9] Subashini, P., Krishnaveni, M., Ane, B.K., Roller, D.: An optimum threshold based segmentation for ice detection in SAR images using Gabor filter. In: Proceedings of International Conference on Computing, ICC 2010, New Delhi, December 27 - 28 (2010)
[10] Abraham, A., Liu, H., Grosan, C., Xhafa, F.: Nature Inspired Metaheuristics for Grid Scheduling: Single and Multiobjective Optimization Approaches Metaheuristics for Scheduling: Distributed Computing Environments. SCI, pp. 247–272. Springer, Germany (2008) ISBN: 978-3-540-69260-7
[11] Abraham, A., Grosan, C., Ramos, V.: Swarm Intelligence and Data Mining. SCI, p. 270. Springer, Germany (2006) ISBN: 3-540- 34955-3