Combined Wavelet and Contourlet Denoising of SAR Images

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ABSTRACT

Synthetic aperture radar (SAR) images are corrupted by speckle noise due to random interference of electromagnetic waves. The speckle degrades the quality of the images and makes interpretations, analysis and classifications of SAR images harder. Therefore, some speckle reduction is necessary prior to the processing of SAR images. The speckle noise can be modeled as multiplicative Rayleigh noise. Logarithmic transformation of SAR images convert the multiplicative noise models to additive *i.i.d.* Rayleigh noise.

In this paper, a combination of wavelet and contourlet transforms will be used for denoising SAR images. The contour transform was introduced by Do and Vetterli in [1] and is a multidirectional and multiscale transform that is constructed by combining the Laplacian pyramid with the directional filter bank (DFB). The pyramidal filter bank structure of the contourlet transform has very little redundancy, which is not ideal for denoising application. Therefore, da Chuna *et al.* [2] introduced the *nonsubsampled contourlet transform* which is a fully shift-invariant, multiscale, and multidirection expansion of the contourlet transform. The nonsubsampled contourlet transformation has been used for example in speckle reduction for SAR images [3].

Here we use the undecimated wavelet transformation to denoise the homogeneous era of the image. But separable wavelets in 2-D provide limited directionality, and thus fail to capture the smoothness along the contours. The nonsubsampled contourlet transform, provides an efficient directional representation and also efficient in capturing intrinsic geometrical structures of the natural image along the smooth contours (edges) [2]. Remote sensing images have presence of natural and man-made objects, which indicate higher geometrical content. Thus, spatial transformations which take into consideration the geometric structure along with other properties of wavelet transformation will be more useful for primitive feature extraction.

This paper uses both the time invariant adaptive combined method (ACM) and pixel by pixel (PBP) method for denoising SAR images [4]. In both these methods, the undecimated discrete wavelet transform is used to code homogeneous areas of the SAR image while the nonsubsampled contourlet transform is used to code areas with edges. By combining the attributes of both transformations, it is possible to denoise SAR images better than by using the wavelet and contourlet denoising methods individually. As an example, denoising methods wrinkles (side-band effects) near discontinuities are greatly reduced compared to using either wavelet or contourlet denoising methods individually.

The segmentation between homogeneous areas and areas with edges is done using total variation segmentation. We use binary version of the TV-based segmentation method is used and an automatic threshold is calculated which separates the histogram of the TV-image obtained into two classes of intensities where one class represents homogenous areas while the other class represents the edges in the SAR image.

The thresholding for the undecimated wavelet transformation denoising is performed by hard thresholding the undecimated wavelet coefficients [5]. Since the undecimated wavelet transformation is norm-preserving, the noise variance is the same for all its wavelet coefficients. Therefore, every coefficient is thresholded with the same value. The variance and the mean used for integer looks were obtained by [6]. In [3] it was observed that the contourlet probability function at different scales is in congruous agreement with the Gaussian model. The thresholding for the nonsubsampled contourlet denoising was also performed with hard thresholding where the threshold value is K times the variance. Different values of K were used for finest scales then for the remaining ones. In order to evaluate the denoising methods, both a simulated SAR image, based on the well-known Lena image and a real SAR image were used. The real SAR image used in the experiments is 8-bit single-look ERS-1 SAR image which shows a portion of the glacier Kotlujokull in the southern part of Iceland. It is a summertime image showing the glacier and the landscape.

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