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EDGE DETECTION IN SPECKLED SAR IMAGES USING WAVELET DECOMPOSITION

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ABSTRACT: In this paper we propose an integration of speckle reduction and edge detection in synthetic aperture radar (SAR) images by using overcomplete wavelet decomposition. The input image is decomposed in multiple level without downsampling, as resolution needs to be preserved. For each subband, a threshold value is estimated according to the noise variance and used for soft-thresholding to reduce speckle. The points of sharp variation (edges) induce modulus maxima in highpass subbands, and the local maxima are detected to produce single-pixel edges. Depending on the requirement of details desired in the edges the level of decomposition can be selected. The method is successfully applied to JERS-1/SAR images, and some experiments are given.

1. INTRODUCTION

Synthetic Aperture Radar (SAR) has the advantage of high resolutions in range and azimuth directions and provides an all-time and all-weather surveying. It has been used to estimate features like the dampness of soil, the thickness of the forest, or the roughness of the sea. The imaging theories of SAR system and optical system are totally different. This makes the visual interpretation of SAR image become very important. Because SAR is a kind of coherence radar system, its image will be degraded by speckle. The existence of speckle limits the application of SAR image. Therefore, speckle reduction is an important and essential procedure in most target detection and recognition system.

Edge detection is a fundamental issue in image analysis. Due to the presence of speckle, which can be modeled as a strong multiplicative noise, edge detection in SAR images is very difficult and methods developed for optical images are generally applied after a process of speckle reduction. On the other hand, an approach based on wavelet transform has been proposed both for speckle reduction (Thitimajshima, 1998; Zhang, 1998) and edge detection (Mallat, 1992; Manian, 1999). In stead of performing these two tasks separately, we propose to incorporate speckle reduction and edge detection in SAR images as a single process.

The proposed method is described in Section 2, including wavelet thresholding and mutiscale edge detection techniques. Section 3 presents the experimental results on a JERS-1/SAR image. Finally, Section 4 provides a conclusion of the paper.

2. THE PROPOSED METHOD

In our method, the logarithmic function is first applied on the image gray levels to convert the multiplicative noise into the case of an additive noise. The multilevel overcomplete wavelet decomposition is then performed and the soft-thresholding on all highpass subbands is used to reduce the speckle noise. The edge detection is applied on the resulted subbands, and the single-pixel edge images are finally obtained by means of local maxima detection. The diagram of this method is depicted in Figure 1.

2.1 Wavelet Thresholding

The theoretical formalization of thresholding in the context of removing noise via thresholding wavelet coefficients was presented by (Donoho, 1995). The key idea of wavelet thresholding is that the wavelet representation can separate the signal and the noise. Assume $f(x, y)$ is a given SAR image of size MxN. At each scale j with $j > 0$ and $S_0 f = f(x, y)$, the wavelet transform decomposes $S_{j-1} f$ into three wavelet bands: a lowpass band $S_j f$, a horizontal highpass band $W_j^H f$ and a vertical highpass band $W_j^V f$. The three wavelet bands ($S_j f$, $W_j^H f$,

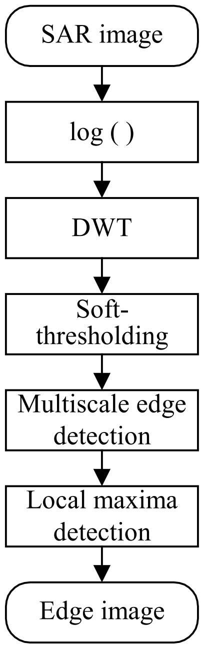


Figure 1: Diagram of the proposed method.

$W_j^V f$) at scale j are of size MxN, which is the same as the original image, and all filters used at scale j $(j>0)$ are upsampled by a factor of 2^j compared with those at scale zero.

The threshold is estimated from each wavelet subbands. In our research, the standard deviation weighted by a scaling factor is used:

$$\lambda_{b,l}(e) = f_a \sigma_{b,l} = f_a \sqrt{\frac{1}{N-1} \sum \left(C_{b,l} - m\right)^2} \tag{1}$$

where N is the number of the image data, m the mean of wavelet coefficients $C_{b,l}$, with b represents each of the high-frequency bands and l the number of decomposition levels, and f_a a scaling factor which is systematically assigned to $1/l$. The soft-thresholding is performed on all bands, with the exception to the lowest-frequency band.

2.2 Multiscale Edge Detection

The method of multiscale edge detection described in (Mallat, 1992) is used to find the edges. This wavelet is nonsubsampled wavelet decomposition essentially implement the discretized gradient of the image at different scales. At each level of wavelet transform the modulus of the gradients can be computed by:

$$M_j f = \sqrt{\left|W_j^H f\right|^2 + \left|W_j^V f\right|^2} \tag{2}$$

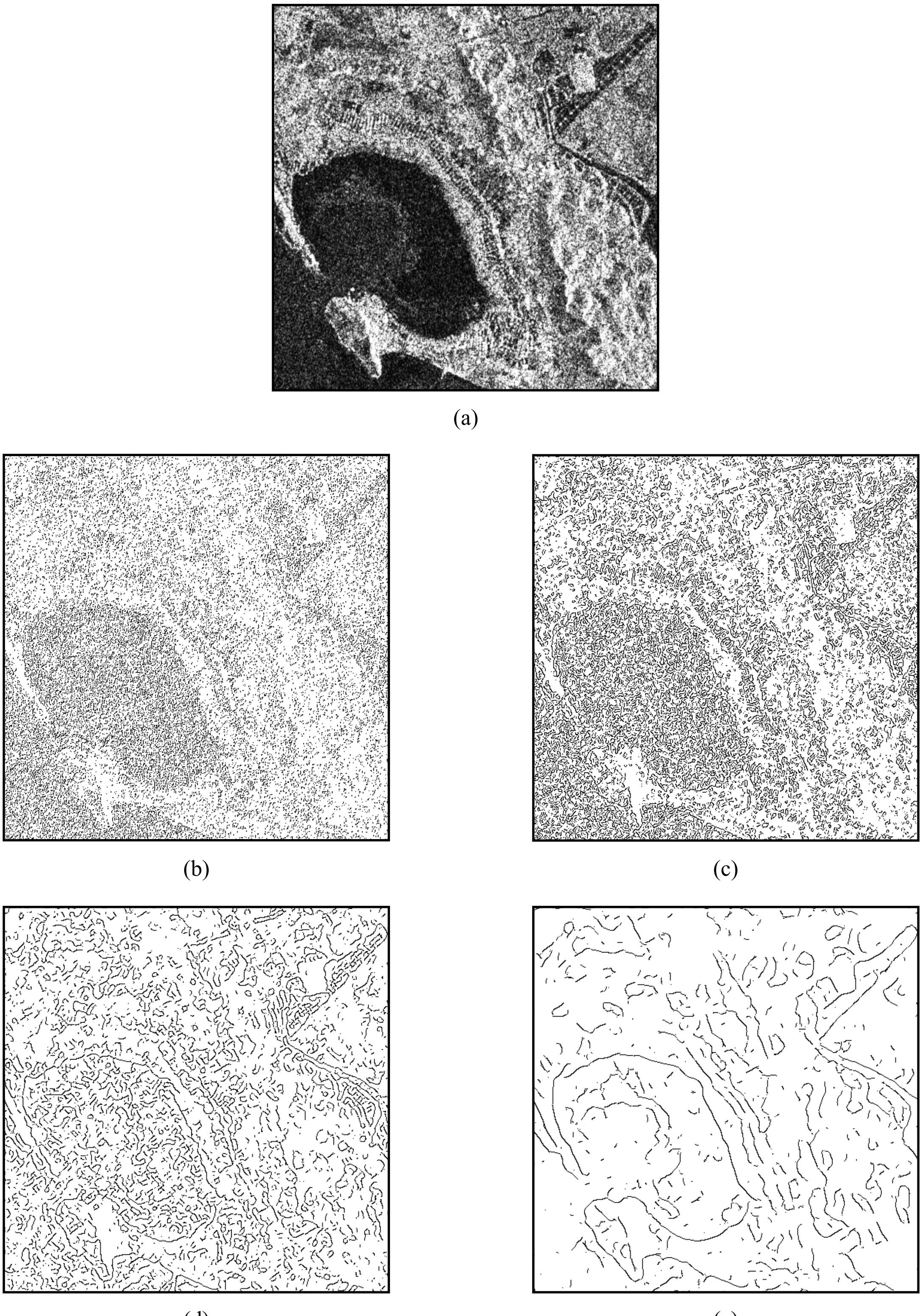
and the associated phase $A_j f$ is obtained by:

$$A_j f = \tan^{-1}\left(\frac{W_j^V}{W_j^H}\right) \tag{3}$$

At each decomposition level we eliminate insignificant edge by taking into account only the pixels with modulus superior to a threshold level. This threshold is calculated from the root mean square of the entire modulus in each decomposition level. The edge points are selected as the pixel with locally maximum in one-dimension neighboring pixel along the direction given by $A_j f$.

3. EXPERIMENTAL RESULTS

Experiments were carried out for the proposed algorithm using different JERS-1/SAR images. An example on the image of Chantraburi (Thailand) with four levels of decomposition is given in Figure 2. Depending on the requirement of details desired in the edges the level of decomposition can be selected.



(a) (b) (c) (d) (e)

Figure 2: Experimental results. (a) Original image. (b)-(e) Edge images obtained at the level 1-4 respectively.

4. CONCLUSION

In this paper we have presented an efficient method to detect edge in SAR images. Since both speckle reduction and edge detection are performed on the same wavelet domain, this makes more compact to incorporate them as a single process.

5. ACKNOWLEDGEMENT

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