INCORPORATING EDGE INFORMATION INTO WAVELET THRESHOLDING FOR IMAGE DENOISING

Rangsanseri Y., Thitimajshima P.

Department of Telecommunications Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok 10520, THAILAND
Tel: (66 2)326-4242, Fax: (66 2)326-4554
Email: rangsanseri@yahoo.com, ktpunya@kmitl.ac.th

Abstract. In this paper, an image denoising technique is viewed as a combination of multiscale edge detection and wavelet thresholding. The image is transformed by using the multiscale wavelet decomposition. The edge regions can be detected from the modulus of the gradient vector of its wavelet coefficients across scales. For each high-frequency subband, a threshold value is to be estimated, by taking the standard deviation of the wavelet coefficients, and used for the soft-thresholding operation. The final image is obtained by reconstruction from the thresholded coefficients. A simulation is performed on many real images and showed that the proposed method gives a significant noise removal and preserves the sharp features of the images.

I. INTRODUCTION

Typical noise-non-edging methods are not well suited to preserve edge structures in the images. Classical operators are based on the local variance statistics. Recently a novel approach for noise reduction due to (Donoho, 1995) has been established. It employs thresholding in wavelet domain. Moreover, the same method can be used in a wide variety of related problems such as data compression and statistical estimation (Donoho, 1993). An improvement is proposed, in this paper, by applying the thresholding only to the wavelet coefficients that correspond to non-edge regions, and keeping edge-like regions intact.

II. THE PROPOSED METHOD

The basic of our proposed method, we first perform a segmentation to identify the edge regions based on multiscale edge detection, or less exactly, to identify the non-edge regions of the images. The wavelet decomposition is performed on the image gray levels. We find a simple and very effective way to estimate threshold value by taking the standard deviation in each highpass band and used for the soft-thresholding operation except the edge regions, in all highpass bands. The final image is then obtained by reconstruction from the thresholded coefficients.

A. Region Segmentation

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. Assume $f(x,y)$ is a given SAR image of size $M \times N$. 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 ($S_j f$, $W_j^H f$, $W_j^V f$) at scale *j* are of size $M \times N$ which is the same as the original image, and all filters used at scale *j* $(j > 0)$ are upsampled by a factor of $2^j - 1$ compared with those at scale zero.

At each scale *j*, the modulus of the gradient vector is proportional to

$$M_{2^j} f(x,y) = \sqrt{\left|W_{2^j}^V f(x,y)\right|^2 + \left|W_{2^j}^H f(x,y)\right|^2} \tag{1}$$

The angle of the gradient vector with the horizontal direction is given by

$$A_{2^j} f(x,y) = \text{argument}(W_{2^j}^H f(x,y) + i W_{2^j}^V f(x,y)) \tag{2}$$

The sharp variation points are the points (x,y), where the modulus $M_{2^j} f(x,y)$ has a local maxima in the direction of the gradient given by $A_{2^j} f(x,y)$. We record the position of each of these modulus maxima as well as the values of the modulus $M_{2^j} f(x,y)$ and the angle $A_{2^j} f(x,y)$ at the corresponding locations.

B. Wavelet Thresholding

The theoretical formalization of thresholding in the context of removing noise via thresholding wavelet coefficients was presented by (Donoho, 1995). The idea is that, in wavelet domain, coefficients insignificant relative to the threshold are likely due to noise, whereas significant coefficients are important signal structures. There are two thresholding schemes: (a) hard-thresholding and (b) soft-thresholding.

Donoho shown that if the error or noise is bound then soft-thresholding is optimal. In general, the noise is uniformly distributed over all levels and show clearly in high-frequency bands. The soft-thresholding is therefore should be performed on all bands, with the exception to the lowest-frequency band. In this paper, we performed soft-thresholding in non-edge region of highpass bands. Moreover, in our method, the thresholding is applied only to the coefficients corresponding to non-edge regions.

IV. RESULTS AND CONCLUSION

In this paper, we have illustrated that it is very efficient to associate edge information to a wavelet thresholding procedure. A simulation is performed on many real images and showed that the proposed method gives a significant noise removal and preserves the sharp features of the images. To achieve higher image quality, we should classify the image into more types of regions, such as edge regions, smooth regions, and texture regions, and use different threshold values adapting to each type of regions.

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