Speckle noise reduction in SAR images using an adaptive wavelet Shrinkage method

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ABSTRACT

Although Synthetic Aperture Radar(SAR) is a very powerful and attractive tool, automatic interpretation of SAR images is extremely difficult because of several reason. Spatially, speckle noise reduction in SAR images is important step to interpret the SAR image at the preprocessing step.

The speckle noise in SAR images is modeled to be multiplicative, and therefore, a signal-dependent noise. So, it has defeated many image-denoising algorithms that are based on additive noise model.

In this paper, we propose an adaptive wavelet shrinkage method for speckle noise reduction in SAR images by analyzing the high frequency level in detail.

We first decompose minutely the high frequency level to analyze the noise level. And then, we determine the weighting threshold value per the level, and layer. Finally, using those weighting threshold, we produce the efficient wavelet shrinkage method. So, this method not only reduces the speckle noise, but also preserves image detail and sharpness.

Ⅰ. Introduction

Speckle noise, which is resulted in reflecting from rough surfaces when radar observes the earth, is caused to be overlapped with different phase signals within the same cell. It shows the granular pattern.

As we known, speckle noise is modeled to be multiplicative, that is signal-dependent noise. So, it has defeated many image-denoising algorithms that are based on additive noise model.

Among the several methods to reduce that noise in SAR image, wavelet analysis[1],[3],[4] has been spotlighted in the noise reduction method. Wavelet analysis can express the signal with the locality about time and frequency, so profit to analyze the image data with the non-stationary process. Particularly, due to noise is sensitive to high frequency level, wavelet analysis is easy to separate the noise part and information part from denosing image.

Applying general Gaussian noise reduction algorithm to SAR image, Seisuke Fukuda and Haruto Hirisawa[3] proposed speckle noise reduction algorithm that transformed the multiplicative-noising RADAR image to an additive-nosing image using the logarithm transform. And another method was to reduce noises from the high-frequency quantization in the image compression.[4]

But, actually, it is very difficult to separate the multiplicative noise part from the SAR image.

In this paper, we propose an adaptive wavelet shrinkage method for speckle noise reduction in SAR images by analyzing the high frequency level in detail.

We first decompose minutely the high frequency level to analyze the noise level. And then, we determine the weighting threshold value per the level, and layer. Finally, using those weighting threshold, we produce the efficient wavelet shrinkage method. So, this method not only reduces the speckle noise, but also preserves image detail and sharpness.

Ⅱ. Wavelet Analysis

1) Wavelet Shrinkage

Typical wavelet filter method is wavelet shrinkage method. That method started from the assumption that noise has uniformly distribution in all frequency level, but information can be described by the a few coefficients[2]. In that assumption, this filtering method adopts to delete (hard threshold) or shrink (soft threshold) smaller coefficients than threshold value within definite levels.

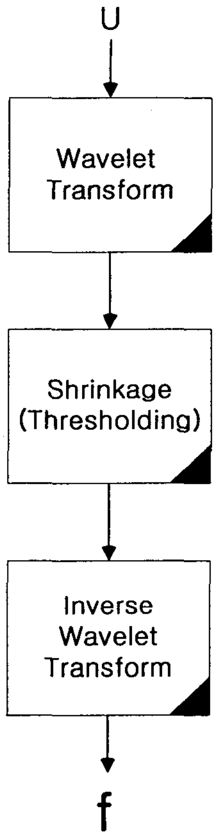

Fig. 1. Wavelet Shrinkage Method.

2) Wavelet Packet

From a view-point of time-frequency, wavelet transform is a characteristic that the low frequency level has the narrow bandwidth and the high frequency level has the wide bandwidth. But, this characteristic has a weakness in a field to analyze the part of high frequency carefully. For example, in the case of compressing the image in which high frequency parts are very important, like a medical image, finger print, and satellite image, it is necessary to handle carefully these parts for compressing the image with minimum loss. In that case, alternative proposal of wavelet analysis is wavelet packet analysis. Because it decomposes the signal finely, that analysis offers good algorithm in a field to need a fine analysis of high frequency part.

Ⅲ. Proposed Method

1) Wavelet shrinkage method based the wavelet packet analysis.

As shown above, wavelet packet analysis gives much information to us about high frequency level. So, it is necessary to analyze high frequency information in detail for reducing speckle noise efficiently.

First, we construct the wavelet packet centering detail level, and independently separate the noise per wavelet basis. Figure 2 is wavelet packet map of this paper. And Figure 3 is wavelet packet image by figure 2.

As shown the Figure 3, we can view that there are so much information in the detail wavelet basis level.

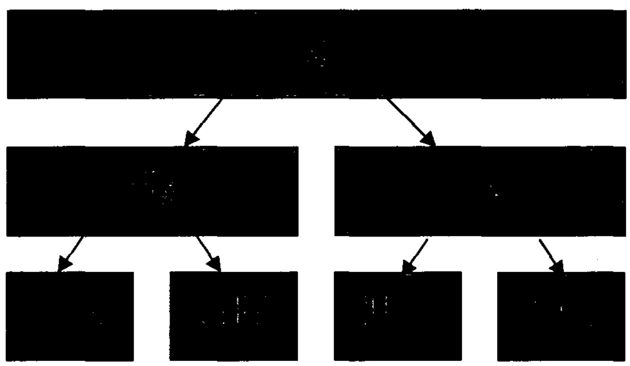

Fig 2. Wavelet Packet Map.

$$W_{2n}(x)=\sqrt{2}\sum h_k W_n(2x-k) \qquad (1)$$

$$W_{2n+1}(x)=\sqrt{2}\sum g_k W_n(2x-k) \qquad (2)$$

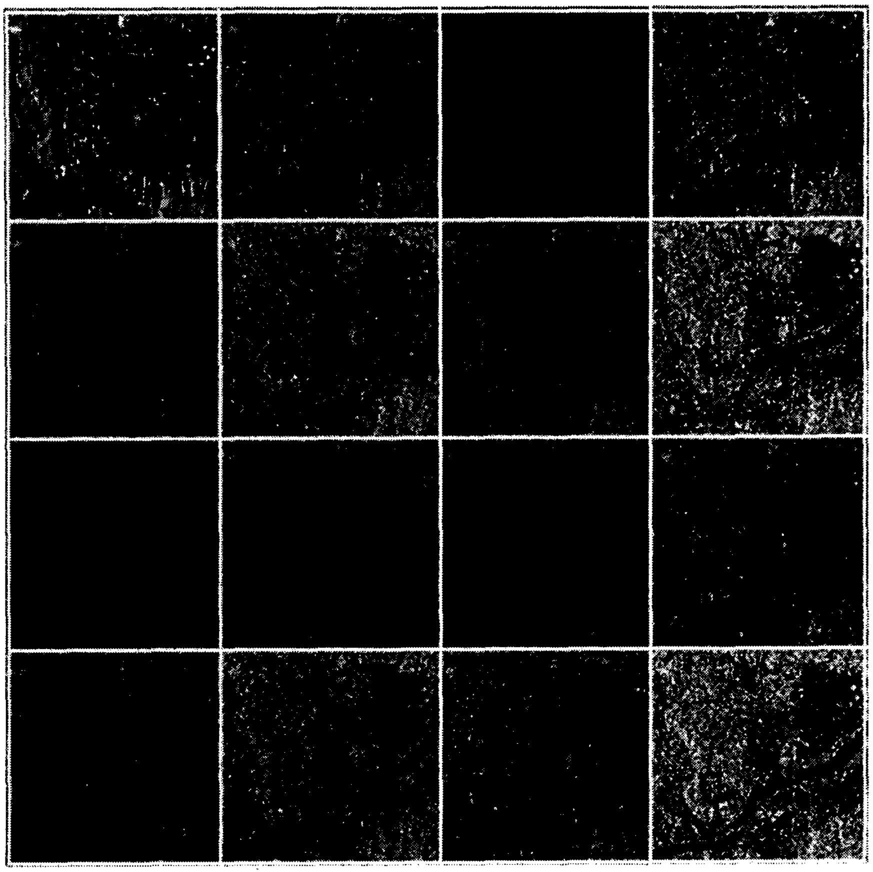

Fig. 3. Wavelet Packet Image.

2) Scaling factor

Donoho, etc proposed the wavelet shrinkage method[2] that is noise reduction method based wavelet threshold to estimate the original image from the noised images. This method offers simple and efficient reconstruction algorithm. In general, wavelet shrinkage have two threshold mechanism: 1) hard threshold, 2) soft threshold.

Hard threshold :

$$T^{hard} = \begin{cases} x & if|x| \geq \lambda \\ 0 & if|x| < \lambda \end{cases} \tag{3}$$

Soft threshold :

$$T^{soft} = \begin{cases} x - \text{sgn}(x)\lambda & if|x| \geq \lambda \\ 0 & if|x| < \lambda \end{cases} \tag{4}$$

In SAR Image, speckle noise is modeled to be multiplicative, that is signal-dependent noise. . The speckle noise is amplified in the area with high backscattered intensity and attenuated in the area with low intensity. In other words, the noise level changes with the backscattered intensity.[4]

For that reason, it has defeated many image-denoising algorithms that are based on additive noise model.

Therefore, we use the scaling threshold that considers the root wavelet coefficient value located in the LL-band.

$$Scaling\ factor(\rho) = LLBand(i,j) / Median(LL\ band) \tag{5}$$

where

LLBand(i,j) : the pixel in the lowest frequency level
Median(band) : median value within the band.

Using that scaling factor, we will shrinkage the noise in the detail level per level and layer independently.

This procedure is following.

Step 1. Decompose the image using the wavelet packet analysis

Step 2. Set up the independent threshold per wavelet basis $\rho_k^l = median(W_k^l)$

Step 3. Calculate the adaptive threshold per wavelet basis level.

$$\sigma(i,j) = k \times \rho_k^l \qquad (6)$$

where $k = S(i,j) / median(S)$

S : lowest frequency level

Step 4. Run Wavelet Shrinkage method considering scaling factor.

Step 5. Reconstruct the image.

Ⅳ. Simulation and Results

RADARSAT Image offers data with various resolution and observational angle.

Among various mode, we used the RADARSAT fine mode, SLC(Single Look Complex) image, and 32 bit amplitude for reducing the quantization distortion. And the image size are 1000×1000 pixels.

Test image was formed by various configuration of the ground like a river, rice fields, and mountains, and had much speckle noises.

Actually, it is a general step to synthesize the image until the 3~4 level in the general wavelet shrinkage method. But, this test synthesized the image until 2 level, and procedured the proposed method on only 1 level, for testing the performance in high frequency information. And then we compared the image by the proposed image with that by the general wavelet shrinkage techniques, and original image.

Figure 4 shows original SLC image, general filtered image being processed by wavelet shrinkage method, and image being processed by proposed method. And Images of right hands shows the zoom-in image of original image.

In the case of general filtered image, we could see that the edge of the rice field was blurred in the entire region. On the other hand, the proposed method could be seen that the edge part was well preserved relatively.

That was because general filtered method was impossible to analyze the detailed part for the wide frequency level, but proposed method processed that levels in detail. So, could be preserved important information that was removed by the general wavelet shrinkage.

Ⅴ. Conclusion

In this paper, we propose an adaptive wavelet shrinkage method for speckle noise reduction in SAR images by considering for the spectral characteristics between wavelet decomposition levels.

We first decompose minutely the high frequency level to analyze the noise level. And then, we determine the weighting threshold value per the level, and layer. Finally using those weighting threshold, we produce the efficient wavelet shrinkage method. So, this method not only reduces the speckle noise, but also preserves image detail and sharpness.

As shown the upper result, in case of the de-noising processing on SAR image, we could ascertain that wavelet packet analysis is better than the wavelet analysis, and that it is efficient to separate speckle noise with noised image with proposed adaptive threshold method.

But, this paper analyzed the image with simple wavelet packet analysis that decomposes only high frequency level. So, it is necessary to design the optimal wavelet basis much more.

References

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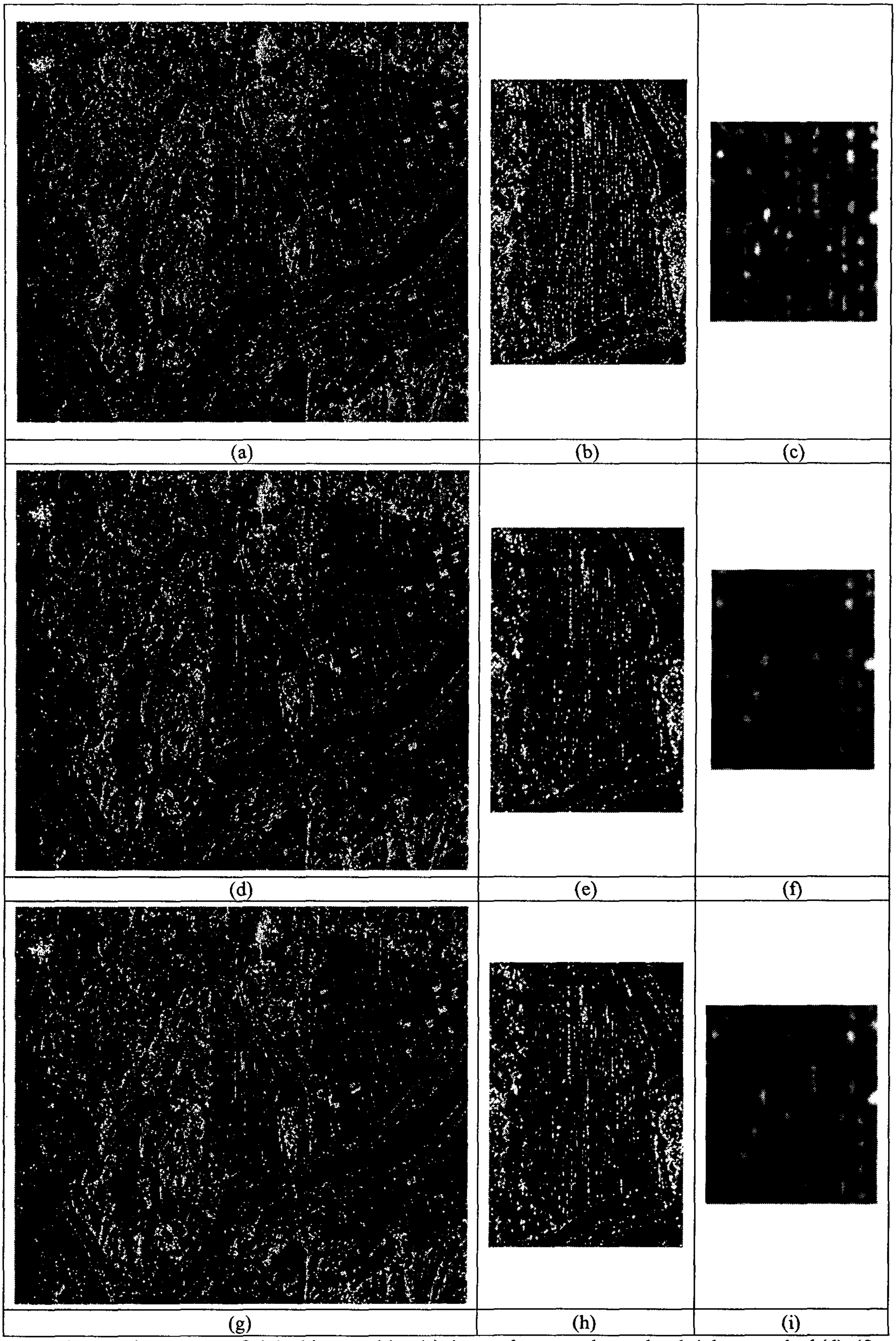

Fig.4 Result Images : Original images (a) ~ (c), images by general wavelet shrinkage method (d)~(f), images by proposed method (g)~(i).