

Speckle Noise Reduction in SAR Images Using Double-Density Dual Tree DWT

Hadeel Nasrat Abdullah, Mohammed Fadhil Hasan and Qussay Salim Tawfeeq
Department of Electrical and Electronic Engineering, University of Technology, Iraq

Abstract: Synthetic array technology permits the achievement of very high mapping resolution in azimuth direction and is obtained by the synthesis of radar data obtained over a considerably longer aircraft flight path than the azimuth resolution cell. Synthetic Aperture Radar (SAR) images are inherently affected by multiplicative speckle noise, which is due to the coherent nature of the scattering phenomenon. This study describes a method of speckle reduction in Synthetic Aperture Radar (SAR) images based on the double density dual tree Discrete Wavelet Transform (DWT).

Key words: SAR, speckle reduction, denoising, double density, dual tree

INTRODUCTION

Synthetic Aperture Radar (SAR) is a coherent imaging sensor based on the technique, where the synthetic aperture, which is a very long antenna synthesized by moving a small one along a convenient path and then properly processing the received signals. Both amplitude and phase of the received signal must be recorded to synthesize the receiving antenna. The processing operation, typically performed digitally, leads to an along path resolution independent from the sensor altitude (Ali *et al.*, 2007).

It produces high resolution images of earth's surface by using pulse compression technique. Synthetic aperture radar has important role in gathering information about the surface of earth because it can operate under all kinds of weather condition (whether it is cloudy, hazy or dark). However, acquisition of SAR images faces certain problems. SAR images contain speckle noise, which is based on multiplicative noise or Rayleigh noise. However, the automatic interpretation of SAR images is often extremely difficult due to speckle noise. Appearing as a random granular pattern, speckle seriously degrades the image quality and hampers the interpretation of image content (Achim *et al.*, 2001).

Speckle noise is generated due to constructive and destructive interferences of multiple echoes returned from each pixel. As a result a granular pattern is produced in the radar image which corrupts significantly the appearance of the image objects. Speckle noise can be modeled as multiplicative random noise in spatial domain.

Reduction of speckle noise is one of the most important processes to increase the quality of radar

coherent images. Image variances or speckle is a granular noise that inherently exists in and degrades the quality of the active radar and SAR images. Before, using active radar and SAR imageries, the very first step is to reduce the effect of Speckle noise (Mansourpour *et al.*, 2006).

Recently, there has been considerable interest in using the wavelet transform as a powerful tool for recovering SAR images from noisy data (Alin *et al.*, 2003). It nevertheless, suffers from a few limitations such as aliasing effects in the transform domain, coefficient oscillations around singularities and a lack of shift invariance. Frames reckoned as more general signal representations, represent an outlet for these inherent constraints laid on basis functions. Redundant DWTs (RDWTs) are shift-invariant nonsubsampling frame extensions to the DWT. They have proved more error or quantization resilient (Caroline *et al.*, 2007), at the price of an increased computational cost, especially in higher dimensions.

They do not however, take on the lack of rotation invariance or poor directionality of classical separable schemes. These features are particularly sensitive in image and video processing. Recently, several other types of frames have been proposed to incorporate more geometric features, aiming at sparser representations and improved robustness (Do and Vetterli, 2005; Kingsbury, 1998).

DOUBLE-DENSITY DUAL-TREE DWT

The double-density DWT and the dual-tree complex DWT are similar in several respects (they are both overcomplete by a factor of 2, they are both nearly shift-

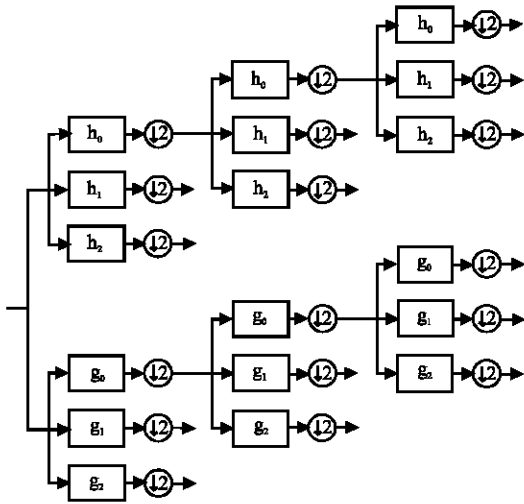


Fig. 1: Iterated filter bank for the double-density dual-tree DWT

invariant and they are both based on FIR perfect reconstruction filter banks), but they are quite different from one another in other important respects. Both, wavelet transforms can outperform the critically sampled DWT for several signal processing applications, but they do so for different reasons (Selesnick, 2004). It is therefore, natural to investigate the possibility of a single wavelet transform that has the characteristics of both the double-density DWT and dual-tree complex DWT. This is the motivation for the development of the double-density dual-tree DWT.

The development of the double-density DWT was motivated in part by the undecimated DWT. The undecimated DWT is exactly shift-invariant and for denoising, it performs substantially better than the critically sampled DWT (Selesnick, 2001).

The double-density dual-tree DWT is based on concatenating 2 oversampled DWTs. The filter bank structure corresponding to the double-density dual-tree DWT consists of 2 oversampled iterated filter banks operating in parallel, similar to the dual-tree DWT. The iterated oversampled filter bank, corresponding to the implementation of the double-density dual-tree, is illustrated in Fig. 1.

SPECKLE NOISE REDUCTION

Noise reduction using the wavelet transform is in generally done by a technique called wavelet shrinking (Donoho, 1995). This technique consists of setting to zero the wavelet coefficients which are lower than a given value. The latter being estimated from speckle variance on the first decomposition level. However, this technique

lacks in the sense that few building blocks (wavelet coefficients) remain to reconstruct the image.

For speckle noise, the standard wavelet thresholding is not effective. Therefore, usual wavelet domain despeckling techniques filter the image logarithm, since after the logarithmic transformation the speckle noise becomes approximately additive Gaussian. The logarithmic transformation itself leads to a biased estimation of the reflectivity, which calls for alternative approaches that filter the wavelet coefficients of the original speckled image. Only a few such methods have been published.

Thus, an artifact will be created in the reconstructed image. The filters used in the wavelet algorithms have a finite spatial extent, which is not zero. Therefore, the calculated value of a given pixel depends on its neighbors. Setting the neighboring coefficients to zero will therefore, modify the value of the analyzed pixel.

THE ALGORITHM

The thresholding method of SAR image using double-density dual-tree DWT can now be described using the following steps (Fig. 2):

- Logarithmically transform the SAR image i.e., compute the intensity SAR image.
- Perform the 2D double-density dual-tree DWT, by tensor product of two 1D double-density dual-tree DWT, to level J. During each level the double-density dual-tree DWT filter bank is applied to the rows first and then to the column of the low/low output from the previous step.
- Compute the threshold value for each sub-band.
- Apply soft thresholding to the double-density dual-tree DWT coefficients obtained in step 2. No thresholding is performed on the low/low output of level J.
- Perform the inverse double-density dual-tree DWT and exponential operation in order to acquire the final SAR image with an improvement in its radiometric quality.

EXPERIMENTAL RESULTS

Experiments were carried out for the proposed algorithm using different SAR images. An example is given in Fig. 3. At first, the natural logarithm was taken for each pixel value of the original *Pentagon* SAR image, which is shown in Fig. 3(a). Then the logarithmic image was decomposed by a 2-level double-density dual-tree DWT. A threshold value was estimated and used for the



Fig. 2: Block diagram of the speckle suppression algorithm

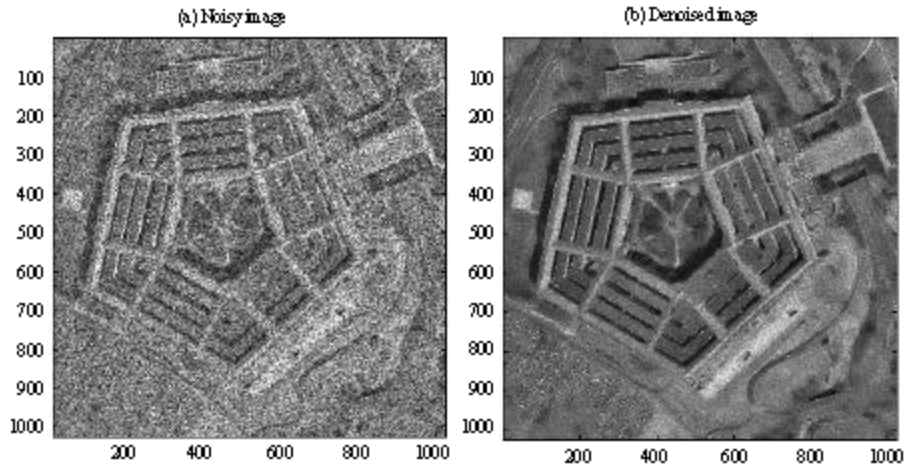


Fig. 3: *Pentagon* Image a) Noisy Image with MSE = 24.3970, SNR = 15.3664 b) Denoised Image with MSE = 12.8321, SNR = 20.7869 , PSNR = 18.5239

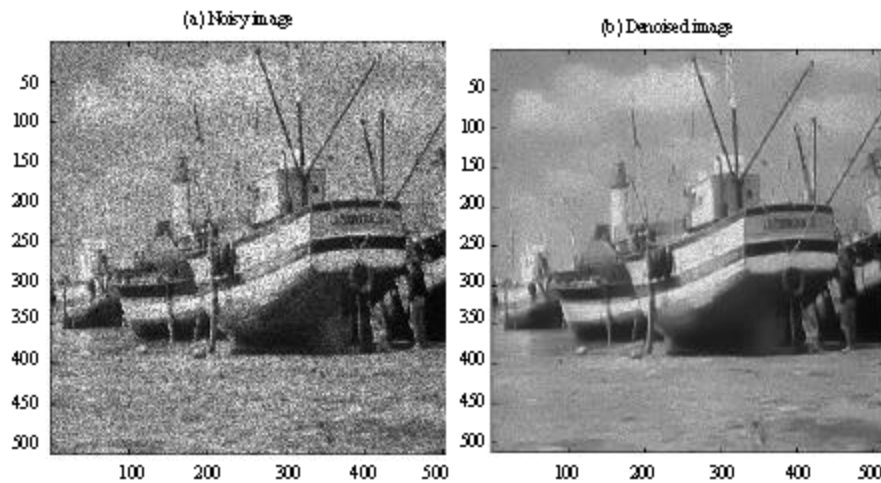


Fig. 4: *Boat* Image a) Noisy Image with MSE=23.6686, SNR = 15.4178 b) Denoised Image with MSE = 13.5639, SNR = 20.0728, PSNR=18.4035

soft-thresholding which was performed on all the high frequency subimages. The exponential function was applied to the reconstructed logarithmic image in order to get back the conventional pixel values of the filtered image, as shown in Fig. 3(b). We also chose to apply it on the classical boat image as shown in Fig. 4.

The quantitative measures for 2D denoising namely MSE (mean square error) and PSNR (Peak signal to noise ratio) are determined as:

$$MSE = \frac{1}{NM} \sum_{n=1}^N \sum_{m=1}^M [s(n,m) - y(n,m)]^2$$

$$PSNR = 10 \log_{10} \left(\frac{255}{\sqrt{MSE}} \right)$$

Where,

s : The original image.

y : The recovered image from the noisy image x.

CONCLUSION

This algorithm is simple, but useful in general SAR image applications.

The main advantage of the new method over the majority of existing techniques is that it preserves point reflectors well, while adapting automatically to the local homogeneity in the image.

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