Speckle Noise Reduction in SAR Images

Jaclyn W L Chang
Department of Information Technology and Electrical Engineering
University of Queensland

Abstract

Synthetic aperture radar imagery is contaminated by coherent speckle noise. In order to improve interpretability, noise reduction methods are introduced. In this paper, two methods are investigated. They are the Intensity Summation method and the Soft-Thresholding method. These two methods were implemented and tested using the software Matlab. There are two approaches used to apply the noise reduction techniques and they are the segmentation and the moving segment approach. With the results obtained, we measure the effective number of looks (ENL) and mean square error of the de-noised images to determine the better noise reduction technique. It was concluded that the Soft-Thresholding method is a better noise reduction technique as it retains image structure and reduce speckle noise better than the Intensity Summation method.

1 Introduction

Synthetic aperture radar (SAR) is a coherent imaging sensor. Its all-weather, day and night imaging capabilities coupled with the achievable high resolutions make it a fundamental instrument for Earth and other planet observation. SAR images are accompanied by fluctuation of the intensity called speckle noise that degrades image quality.

There are a number of techniques in which speckle in radar images is reduced. This paper investigates the Intensity Summation method and the Soft-Thresholding method.

2 Speckle Noise

SAR is a coherent imaging technology, recording both the amplitude and the phase of the backscattered radiation. Each resolution cell of the system contains many backscatterers. The phases of the return signals from these backscatteres are randomly distributed and speckle is caused by the resulting intereference. This gives the images a grainy appearance.

3 Performance Measure

With the use of a true image we can compare the filtered image with the true image, which then gives us a true indication of how the filter performed. The mean square error formula is as shown,

$$Q = \frac{1}{N}\sum_{i=1}^{N}\left[X(i) - R(i)\right]^2$$

Where X is the filtered image, R is the true image and N is the number of pixels in the image matrix. A smaller Q indicates a better reduction in speckle noise. When there is no true image to compare the filtered image with, the effective number of looks (ENL) is measured and the equation is as shown,

$$ENL = \frac{\mu^2}{\sigma^2}$$

Where σ is the standard deviation and μ as the mean of the image. The ENL evaluates how smooth the image is.

4 Intensity Summation

The formula for the Intensity Summation method basically replaces each pixel value with a local average as shown in the equation below,

$$X_{IS} = \frac{1}{L}\sum_{i=1}^{L} X_i$$

Where X_{IS} is the average of L nearby pixel values of the matrix of the image X_i with i as the pixel's location.

5 Soft-Thresholding

The approach involves applying a soft-threshold directly to each SAR image pixel than to wavelet coefficients generated from the SAR image. First find the mean of the image, μ_x,

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} X_i$$

Where N is the number of pixels in each image.
Standard Deviation of each image is given by,

$$\sigma_x = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(X_i - \mu_x\right)^2}$$

Then, by applying the soft-thresholding equation, the threshold T_x of each image is given as,

$$T_x = \sigma_x \sqrt{2 \cdot \log N}$$

With the threshold value T_x, the upper and lower thresholds can then be calculated,

$$T_{upper} = \mu_x + T_x$$

$$T_{lower} = \mu_x - T_x$$

The pixel values that are outside the upper and lower threshold limit remain the same but the pixel values that are within the upper and lower threshold limit are changed to a constant value given by the mean value of the image.

6 Segmentation Approach

The image is broken down equally into (n × n) window size segments as shown below.

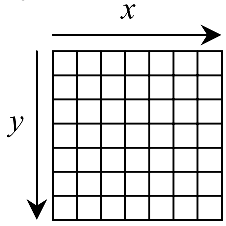

Fig 1. Speckle Image divided equally into (n x n) segments.

Noise Reduction Algorithms are applied to every segment from the left to the right of the Speckle image.

7 Moving Segment Approach

The image is divided equally into segments of size (n × n), where n is an odd number, is stepped, one pixel at a time, across the entire image. At each step, a new (speckle reduced) pixel value is determined for the center pixel of the segment. The figure below shows the method for this approach.

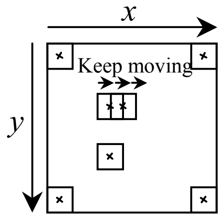

Fig 2. Segment moves in one-way direction.

8 Performance and Results

The Tables below state the performance of the noise reduction techniques on the simulated image.

IS (Segment)	Original ENL	Noisy ENL	De-noised ENL	Noisy Image, Q	De-noised Image,Q
n = 2	0.78031	0.628	2.546	0.35575	1.0917
n = 4	0.78031	0.60313	10.1282	0.36176	1.2772

IS (Moving)	Original ENL	Noisy ENL	De-noised ENL	Noisy Image, Q	De-noised Image, Q
n = 3	0.78031	0.61449	4.2307	0.36347	1.2683
n = 5	0.78031	0.62567	6.3978	0.36439	1.3744

ST (Segment)	Original ENL	Noisy ENL	De-noised ENL	Noisy Image, Q	De-noised Image, Q
n = 2	0.78031	0.60902	2.4581	0.36308	1.0948
n = 4	0.78031	0.62623	0.75414	0.34987	0.1261
n = 5	0.78031	0.62407	0.77973	0.36136	0.084675
n = 10	0.78031	0.61362	0.79924	0.35853	0.020789

ST (Moving)	Original ENL	Noisy ENL	De-noised ENL	Noisy Image, Q	De-noised Image, Q
n = 3	0.78031	0.61168	0.63725	0.36064	0.23059
n = 5	0.78031	0.62658	0.63378	0.3675	0.1633
n = 7	0.78031	0.62546	0.5908	0.36335	0.15758
n = 9	0.78031	0.61578	0.52375	0.35765	0.18164

Fig 3. Table of results for simulated image

From results obtained, we know that soft-thresholding gives the best outcome.

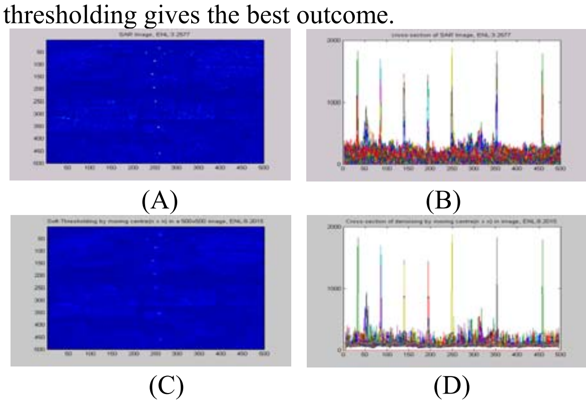

Fig 4. (A)SAR Image; (B)Cross-section of SAR Image; (C)Best Image by ST; (D)Cross-section of ST.

9 Conclusion

It was concluded that the de-noised image by moving segment gave a higher quality de-noised image than the segmentation approach. De-noising by soft-thresholding gives rise to a more accurate result as it retains image structure and effectively reduce speckle. Although the Intensity Summation method yields a larger ENL value, it is not accurate and does not make a good representation of the true image.

References

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Biography

Jaclyn Chang was born in 1979 in Singapore. She is currently undertaking a degree in Electrical Enginnering at the University of Queensland. Jaclyn has acquired a diploma in Electrical Engineering at Ngee Ann Polytechnic, Singapore. She has also gained some work experience at Motorola Electronics, Singapore.