NOISE REMOVAL TECHNIQUES FOR MICROWAVE REMOTE SENSING RADAR DATA AND ITS EVALUATION

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ABSTRACT

Microwave Remote Sensing data acquired by a RADAR sensor such as SAR(Synthetic Aperture Radar) is affected by a peculiar kind of noise called speckle. This noise not only renders the data ineffective for classification, texture analysis, segmentation etc. which are used for image analysis purposes, but also degrades the overall contrast and radiometric quality of the image. Here we discuss the various noise removal techniques which have been widely used by scientists all over the world. Different filtering methods have their pros and cons, and no single method can give the most satisfactory result. In order to circumvent those issues, better and better methods are being attempted. One of the recent methods is that based on Wavelet technique. This paper discusses the denoising techniques based on Wavelets and the results from some of those methods. The relative merits and demerits of the filters and their evaluation is also done.

KEYWORDS

SAR, noise, filtering, speckle, microwave, adaptive, spatial, wavelets.

1. INTRODUCTION

Microwave remote sensing data has some unique features which render them very useful. This is nothing but the capacity to penetrate clouds, fog, smoke etc. It is also capable of sensing during both day and night. Thus microwave and even mm-wave frequencies are increasingly being used for not only civilian remote sensing purposes to cater to tropical and northern hemisphere's foggy weathers, but also for other applications such as medical imaging, and for surveillance and military use. Similarly the polarimetric capabilities render the data useful for different features detection.

However, the noise in the data generated from the active sensors, cause operational detection or utilization methods formulation difficult. Hence techniques to reduce the noise which is multiplicative in nature, are being sought after by researchers in this field.

Jan Zizka (Eds) : CCSIT, SIPP, AISC, PDCTA - 2013
pp. 257–264, 2013. © CS & IT-CSCP 2013 DOI : 10.5121/csit.2013.3629

During the last three decades the noise removal methods hovered around adaptive and non-adaptive techniques using the local image statistics. Both spatial as well as frequency domain methods, have been used with varying degrees of quality improvement on the data sets.

In recent times, the Wavelet methods have gained momentum due to the inherent characteristics of such techniques. Time-frequency data handling renders such methods more amenable to microwave signal's noise estimation and correction. In our study, first some of the well known filtering methods based on spatial domain such as Mean, Median, Lee, Frost etc are used on some of the SAR data sets from spaceborne and airborne sensors. Next some Wavelet based denoising techniques are being attempted for these microwave remote sensors data. The quantitative evaluation of the SNR of the data using the different techniques gives an estimate of the efficacy of the method, and gives us scope of further improvement.

India's first radar imaging sensor on a spaceborne platform, RISAT-1, was launched in April 2012. Data from this sensor is available in different modes, which are being used for our study. Similarly the previous SAR i.e. airborne DMSAR (Disaster Management SAR) has also been used in our study. Different sensor's data in a variety of modes give scope for a rigorous analysis. This study explores the possibility of Wavelet domain filtering on SAR data.

2. SPECKLE NOISE IN MICROWAVE REMOTE SENSING RADAR DATA

Microwave remote sensing, radar data are characterized by a typical noise called speckle, which is multiplicative in nature. This is due to the inherent technique used in acquiring the signal return. SAR imaging is based on integration of a scene coherent response of multiple scatterers from within a resolution cell. This gives rise to constructive and destructive interference of the return signal which in turn gives causes the speckle noise. Thus homogeneous regions will appear non uniform, and edges will lose their sharpness. Such data are not only visually unpleasant, but also unsuitable for image analysis such as classification, segmentation etc. Most of the noise removal techniques used in image processing field deal with additive noise which is generally present in optical data sets. These methods are ineffective for radar data. In section IV we will discuss some of the filtering methods for dealing with speckle noise affected data.

3. WAVELET TRANSFORM

A wavelet is a mathematical function which decomposes a given signal into different scale components. Each scale component has a frequency band assigned to it. It is similar to Fourier transform, but here the mapping is in the frequency versus time domain. Hence the frequency components can be studied with a resolution that matches its scale. Thus a wavelet basically analyses a signal in a time-frequency scale, whereby the properties of the signal can be studied in a very efficient way.

Wavelet transforms have certain advantages over the Fourier transforms as regards to functions that have discontinuities and sharp peaks. These functions can decompose and reconstruct finite, non-periodic and non-stationary signals with a good accuracy.

One can analyze any given signal by using a method called the multi-resolution analysis (MRA). MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. This technique is highly useful for signals which have high frequency components for short durations and low frequency components for long durations. As was discussed in the previous section, the noise in microwave radar data is of granular type(speckle), which is due to sudden variation in the intensity. This is highly amenable for wavelet based filtering. A large number of wavelet transforms exist as of today, and each is suitable for different applications. The common ones are:

(a) Continuous wavelet transform (CWT)

(b) Discrete wavelet transform (DWT)

(c) Complex Wavelet Transform(CmWT)

The basic wavelet function is given as:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \quad (1)$$

$$\psi_{m,n}(t) = a^{-m/2}\psi(a^{-m}t - nb) \quad (2)$$

where a is the scaling parameter and b is the translation parameter. Here m, n are the spatial domain parameters for size and power of the kernel, chosen for operation.

Using these, different denoising filters can be designed for various types of images. In the case of radar data as the noise is not Gaussian in nature, initially scientists attempted to convert the signal to an additive one, by taking logarithm, the used the denoising techniques applicable to such noise, and then again reverted back. This was not suffiecient. Using thresholding techniques[5], good results were obtained for additive noise. Applying the same techniques on converted signals did not give appreciable results. On the other hand, Daubechies wavelet coefficients of different tap sizes yield results which are comparable to standard noise removal filters of [1][2]. Here we have attempted some of the techniques on different types of data sets.

4. SPECKLE FILTERS

The most primitive filter is the mean filter. But a better version of mean filter is the multi-look processing of SAR data, whereby the full bandwidth of the signal is divided into overlapping smaller bandwidth spectrums, and incoherently summed to reduce the speckle noise. This is effective in reducing noise, but at the cost of degraded spatial resolution. Other speckle filters involve both adaptive as well as non adaptive filters[1][2][3]. The other type of non adaptive filter is the median. This is better than mean in terms of preserving edges. But still these are not adaptive to the noise in edges, and in regions of sudden jumps and changes. Hence, the non-adaptive methods such as Lee, Frost, Gamma-map, Kuan, simulated annealing types of filtering have been resorted to, in order to take care of speckle. These are briefly discussed in next section, and the results of applying such filters on spaceborne, and airborne C band SAR datasets are shown, in this paper.

5. RESULTS OF SPECKLE FILTERING

The well known filters such as mean, median, Lee, Frost have been developed by us, and have been tried on some of the data sets. The results are shown here.

(1) Standard Spatial Filters

Multi-look averaging, mean, median, K-mean, sigma, geometric filters are the standard non-adaptive filters in use. Easy to implement, and fast to process, these filters do not preserve the edges while reducing noise. For gross level features these can be used. The non-adaptive filters such as Lee, Frost are better for preserving details while noise is suppressed.

(2) Wavelet Based Filters

The wavelet based filters take advantage of the adaptive nature of the Wavelet transform property. The multi-resolution capability of such transform, gives scope of getting different levels of filtering at different frequency components in the image[5]. Hereby the low and high frequency components can be filtered by selecting the wavelet coefficients properly, or by adjusting the thresholding level. Signal processing has normally taken recourse to Bayesian or linear analysis, since a long time. Donoho[4] gave a simple thresholding representation which can yield nearly optimal non-linear estimates. He has given a simple thresholding criteria given by:

$$T = \sqrt{2\log(n)} \cdot \sigma/\sqrt{n}. \qquad (3)$$

Where n is the number of samples in the area under analysis, and σ is the variation therein.
T is the threshold criteria chosen.

In this study, RISAT-1 images have been used to do filtering using standard methods, and wavelet based methods. This gives us insight into developing new techniques using wavelet tools, in order to suppress radar noise in single as well as multi-polarization data modes, and at the same time preserve the edges. More techniques are coming up recently such as Contourlet based approach[6]. But we have not tried this method here.

Fig1:(a) DMSAR processed image (b) Median Filtered (c) Median + Lee Filtered

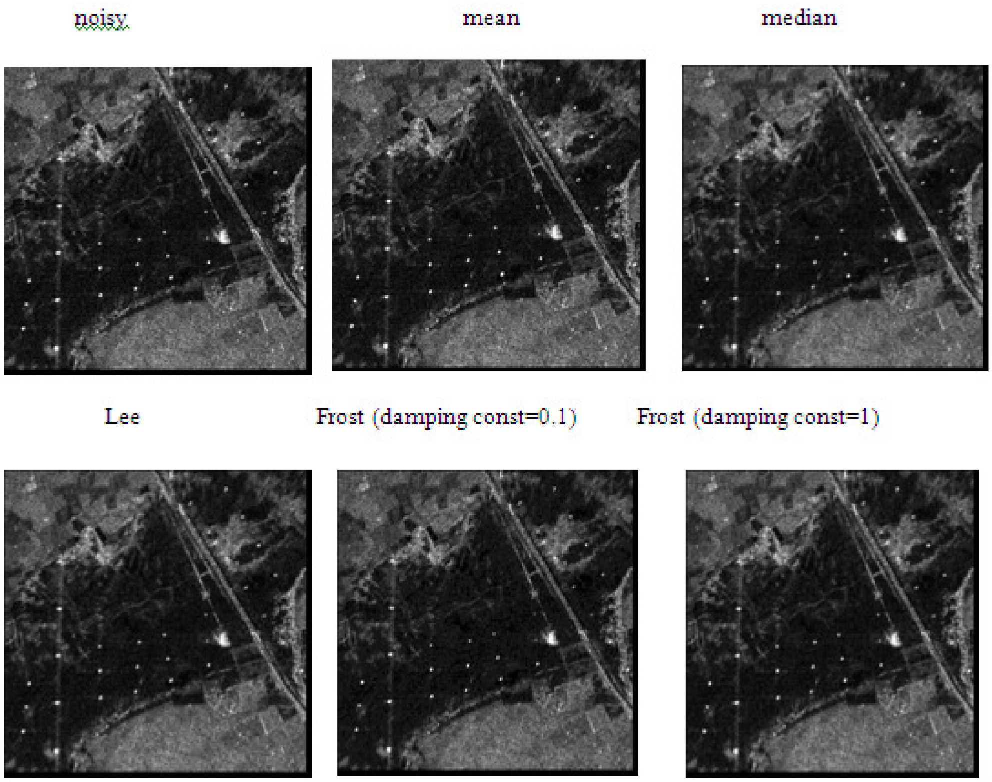
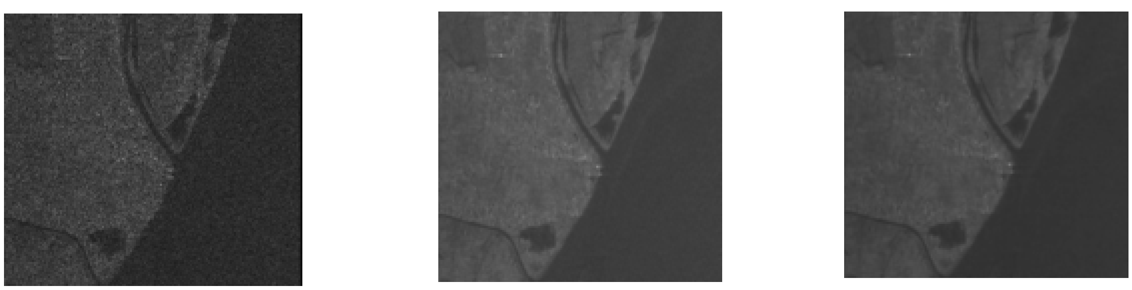


Fig2: (a) DMSAR processed image (b) Mean Filtered (b) Median Filtered (c) Lee Filtered (d) & (e) Frost Filtered with window size 3x3



(a) (b) (c)

Fig3: (a) RISAT-1processed image (b) Lee Filtered (c) Wavelet Filtered

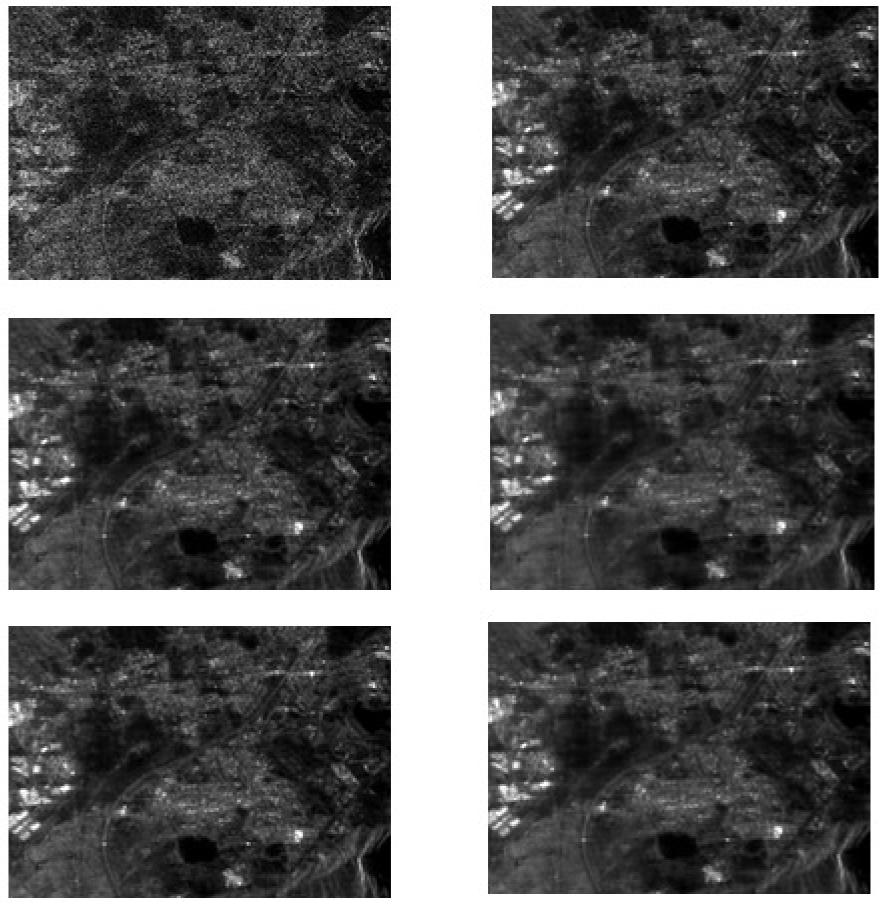


Fig 4: (a) Raw (b) Lee(7X7) &(c) (d) (e) Wavelet Filtered with different coefficients, and thresholds.

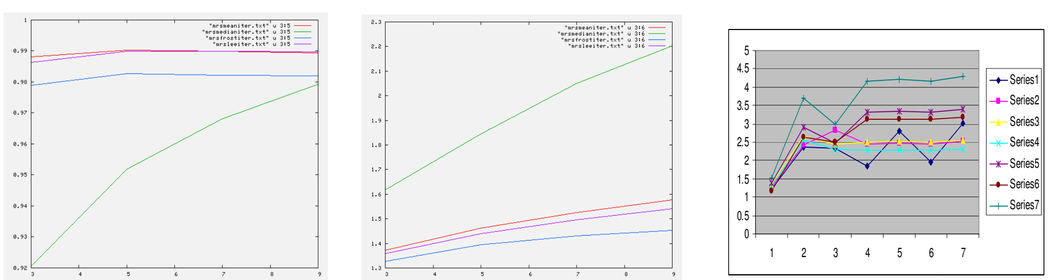


Fig 5(a): Normalised Mean/ Window size 3,5,7,9 Fig 5(b): SNR /Window sizes 3,5,7,9 Fig:5(c) SNR for 7 nearly homogeneous regions, from a scene(2048X2048) of RISAT-1 data set

Filter Performance & Comparison:

The filter practical observation and comparison is done below for the standard spatial filtering methods.

- The arithmetic mean filter reduces the resolution power of the pixel values and blurs the edges while performs well in homogenous area as compared to median filter.

- The median filter used is not adaptive. It helps in preserving the edges and does not blur the image.

- Frost filter's performance is based on the decay constant factor. If we take the value of decay constant very low in the range of 0.1 to 0.5 we see that the image performs almost similar to mean filter while if we take values as 1 or 2 we see that the filter performs well as desired. And if we increase its value to 5 or above we see no filtering at all.

- Lee filter's performance depends on the standard deviation of the homogenous area. The selection of the area is kept user dependent. And the apriori variance is calculated automatically. It was observed that if the deviation value is very low in the order of 0.01 to 0.2 then no filtering takes place. If the value of the standard deviation for Gaussian distribution is taken as 0.28 then the desired performance is obtained. If it is increased further to 2.0 and above, the filter starts performing as a mean filter.

- Fig5(c) shows the SNR of some scene portions (200X200 samples) extracted from the image in 4(a). In X axis, point 1 is for raw image, which shows the poorest SNR, of around 1.3, for most of the images, as expected. 2 is for Lee(window size=3), 3 is for median(window size=3), 4,5,6,7 are for Wavelet based denoising using Daubechies filter with different thresholding and coefficients.

- Wavelet based filters are seen to give results comparable to the adaptive filters, such as Lee, in some of the cases, and better for others. The better SNR image, like Fig 4(e), reduces the noise at the cost of spatial resolution degradation and hence blurring.

- This gives us scope of improvement of techniques, in order to optimize, SNR versus image resolution.

- This study has shown that Wavelet based denoising can give comparable results with standard adaptive filters, such as Lee and Frost, and sometimes better depending on the selected thresholds, as has been demonstrated with ISRO's DMSAR and RISAT-1 data.

6. CONCLUSION

The wavelet based filtering techniques are giving comparable results with standard adaptive filters. However since the normal adaptive filters need different window sizes and several iterations in order to get required levels of denoising it is time consuming. In this regard, Wavelet techniques have the flexibility to adapt to frequencies, and hence new techniques can be evolved to cater to noise at different levels, such as edges and homogeneous areas. This is being attempted in our future study.

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