INVESTIGATION OF THE SPECKLE NOISE FILTERS IN ALOS PALSAR IMAGES

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ABSTRACT: Speckle noise is primarily due to the phase fluctuations of the electromagnetic return signals. Since inherent spatial-correlation characteristics of speckle in SAR images are not exploited in existing multiplicative models for speckle noise. In this paper, we investigate the efficiency of the filters: Kuan, Gamma, Enhanced Lee, and Enhanced Frost filters in reduction of speckle noise in forestry area. Selection of the suitable filter can be played an important role in applications such as estimation of biomass in forestry areas. We employ ALOSPALSAR image use L-band frequency for this investigation. The filters test on different sites in PALSAR image of the northern forests part of Iran.

KEY WORDS: Speckle noise, PALSAR, JERS-1, SAR, biomass, forestry.

1. INTRODUCTION

Both the radiometric and texture aspects are less efficient for area discrimination in the presence of speckle. Reducing the speckle would improve the discrimination among different land use types, and would make the usual per-pixel or textual classifiers more efficient in radar images. Ideally, this supports that the filters reduce speckle without loss of information.

In the case of homogeneous areas (e.g. agricultural areas), the filters should preserve the backscattering coefficient values (the radiometric information) and edges between the different areas. In addition for texture areas (e.g. forest), the filter should preserve the spatial variability (textual information).

Many adaptive filters that preserve the radiometric and texture information have been developed for speckle reduction. Filtering techniques generally can be grouped into multi-look processing and posterior speckle filtering techniques. Multi-look processing is applied during image formation, and this procedure averages several statistically independent looks of the same scene to reduce speckle (Porcello et al. 1976). A major disadvantage of this technique is that the resulting images suffer from a reduction of the ground resolution that is proportional to the number of looks *N* (Martin and Turner 1993). To overcome this disadvantage, or to further reduce speckle, many posterior speckle-filtering techniques have been developed. These techniques are based on either the spatial or the frequency domain.

The Wiener filter (Walkup and Choens 1974) and other filters with criteria of minimum mean-square error (MMSE) are examples of filtering algorithms that are based upon the frequency domain (Li 1988). The Wavelet approaches have been used to reduce speckle in SAR images, following Mallat's (1989a, b) theoretical basis for multi-resolution analysis. Gagnon and Jouan (1997), Fukuda and Hirosawa (1998), and Simard et al. (1998) have successfully applied wavelet transformation to reduce speckle in SAR images. Gagnon and Jouan (1997) presented a Wavelet Coefficient Shrinkage (WCS) filter, which performs as well as the standard filters for low-level noise and slightly outperforms them for higher-level noise. The wavelet filter proposed by Fukuda and Hirosawa (1998) has satisfactory performance in both smoothing and edge preservation.

Adaptive filters based upon the spatial domain are more widely used than frequency domain filters. The most frequently used adaptive filters include Lee, Frost, Lee-Sigma and Gamma-Map. The Lee filter is based on the multiplicative speckle model, and it can use local statistics to effectively preserve edges and features (Lee 1980). The Frost filter is also based on the multiplicative speckle model and the local statistics, and it has similar performance to the Lee filter (Frost et al. 1982). The Lee-Sigma filter is a conceptually simple but effective alternative to the Lee filter, and Lee-Sigma is based on the sigma probability of the Gaussian distribution of image noise. Lopes et al. (1990) developed the Gamma-Map filter, which is adapted from the Maximum a Posterior (MAP) filter (Kuan et al. 1987). Lee, Frost and Lee-Sigma filters assume a Gaussian distribution for the speckle noise, whereas Gamma-Map filter assumes a Gamma distribution of speckle (Lopes et al. 1990a and 1990b). Modified versions of Gamma-Map have also been proposed (Nezry et al. 1991). Nezry et al. (1991) combined the ratio edge detector and the Gamma-Map filter into the refined Gamma-Map algorithm.

In this paper, we investigated the efficiency of the filters: Kuan, Gamma, Enhanced Lee, and Enhanced Frost filters (Lee 1980; Frost et al. 1982; Lopes et al. 1990; Kuan et al. 1987) in reduction of speckle noise in forestry area.

Selection of the suitable filter can be one of the important component in applications such as estimation of biomass for removing speckle noise in the forestry areas. We employ a new Japanese sensor ALOSPALSAR image use L-band frequency. Wu (Wu, 1987) showed the intensity in a SAR image at L-band is proportional to the above ground biomass of the forest stands. So we conducted a forest inventory in the north of Iran to examine these filters.

2. STUDY AREA AND DATA SETS

The study area for this project is the drainage basin of Shafarood in the north of Iran around the city Rezvanshahr (figure 1(a)). It is located between $37^{\circ}24'N - 37^{\circ}40'N$ and $48^{\circ}46'E - 49^{\circ}11'E$. It is representative of the rugged mountainous landscape with various types of trees consist of: Maple, Alder, Conifer, Beech, Hornbeam, Azedarach and Acorn.
Remote sensing data is also a ALOSPALSAR image with a spatial resolution of approximately.

3. METHODOLOGY AND RESULTS

SAR image consists of two components: backscatter coefficient, which contains information about the scene, and speckle fluctuations, which are produced by the imaging process. Both the radiometric and texture aspects are less efficient for area discrimination in the presence of speckle. Reducing the speckle would improve the discrimination among different land use types, and would make the usual per-pixel or textual classifiers more efficient in radar images. Ideally, this supports that the filters reduce speckle without loss of information. In the case of homogeneous areas (e.g. agricultural areas), the filters should preserve the backscattering coefficient values (the radiometric information) and edges between the different areas. In addition for texture areas (e.g. forest), the filter should preserve the spatial variability (textual information).
Many adaptive filters that preserve the radiometric and texture information have been developed for speckle reduction. These filters are based on either the spatial or the frequency domain. Adaptive filters based upon the spatial domain are more widely used than frequency domain filters. The most frequently used adaptive filters include: Kuan, Gamma, Enhanced Lee, and Enhanced Frost filters (Lee 1980; Frost et al. 1982; Lopes et al. 1990; Kuan et al. 1987). These filters are applied on the PALSAR image to find the filter that preserve the texture information for the study area. The ratio of the original intensity image to the filtered image enable us to determine the extent to which the reconstruction filter introduces radiometric distortion so that the reconstruction departs from the expected speckle statistics.
Suppose that the filters yield the true radar cross section (RCS), σ_j, at pixel j. The ratio of the pixel intensity in the PALSAR image to the derived RCS, $r_j = I_j / \sigma_j$, should then correspond to speckle fluctuations alone with a mean value of one. The mean and standard deviation (SD) can then be estimated over the ratio images. When the observed mean value differs significantly from one, it is an indication of radiometric distortion. If the reconstruction follows the original image too closely, the standard deviation would be expected to have a lower value than predicted. It would be larger than predicted if the reconstruction fails to follow genuine RCS variations. This provides a simple test that can be applied to any form of RCS reconstruction filters. The mean and standard deviation values of the ratio images are shown in table 1 for the PALSAR image.

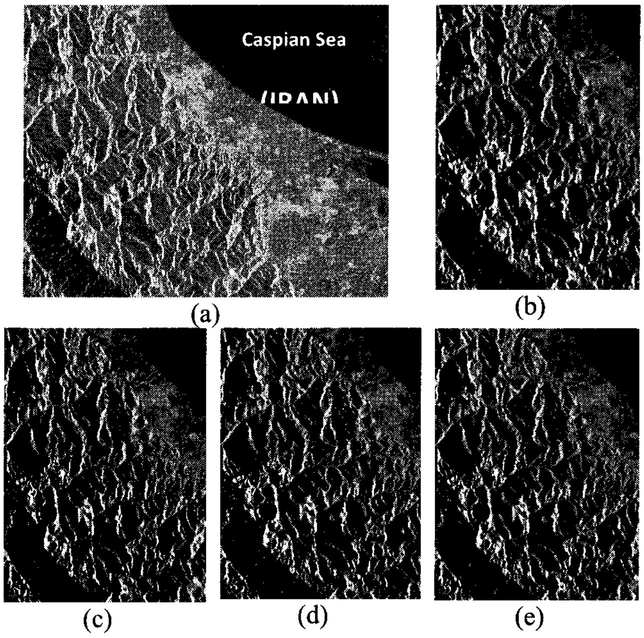

Figure 1. The original and filtered PALSAR images: (a) the original image, (b) the Kuan filter, (c) the Gamma filter, (d) the Enhanced Lee filter, and (e) the Enhanced Frost filter

According to Table 1, the Gamma and Enhanced Lee filters have better results than others filters in this study. In this paper the Enhanced Lee filter with size of 5×5 was chosen after several tests.

Table 1. the mean and SD values of ratio images for the de-speckling filters

Filters	Frost	Kuan	Lee	Enhanced Frost	Enhanced Lee	Gamma
Mean	0.9449	0.9476	0.9545	0.9503	0.9656	0.9564
SD	0.0231	0.0252	0.0224	0.0293	0.0211	0.0211

After reduction the speckle noise, the texture of SAR image must be measured. Of the many describing texture methods, the grey-level co-occurrence matrix (GLCM) is the most common in remote sensing.
Nine texture measures are calculated from the GLCM for a moving window with size of 5×5 pixels that centered in pixel *i, j* of the de-speckled PALSAR image. After the Gram-Schmidt process, just four texture measures: contrast, correlation, maximum probability and standard-deviation were selected as the optimum measures for this area. Thus these features can be used in biomass estimation in the study area.

4. CONCLUSION

In this paper, we investigated the efficiency of the filters: Kuan, Gamma, Enhanced Lee, and Enhanced Frost in reduction of speckle noise in forestry area. Selection of the suitable filter can be played an important role in applications such as estimation of biomass in forestry areas. We employed ALOSPALSAR image for this investigation. The filters tested on different sites in PALSAR image of the northern forests part of Iran. We concluded that the Enhanced Lee filter with size of 5×5 was chosen after several tests

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