A Region-based Approach to the Estimation of Local Statistics in Adaptive Speckle Filters

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Abstract — Radar images are inherently degraded by a strong, multiplicative noise known as speckle. The most frequently used speckle filters are adaptive in the sense that the filtering operation depends on estimations of local statistics calculated on a neighbourhood of the considered pixel. The choice of the neighbourhood is consequently an important issue. In this paper we introduce a new method which uses segmentations obtained prior to filtering. This region-based approach is compared to versions using sliding windows. The study is limited to agricultural scenes composed of distinct parcels of relatively homogeneous reflectivity. Without loss of generality, we have restricted ourselves to the LMMSE filter of Kuan *et al.*

INTRODUCTION

Speckle filtering consists in estimating the true reflectivity R as a function of the intensity I of a pixel and some local statistics calculated on a neighbourhood of this pixel. To obtain precise estimations, the neighbourhood must contain a sufficient number of pixels, but it is equally important that the the image is stationary in the neighbourhood. The problem of estimating the underlying reflectivity is consequently closely related to the detection of non-stationarities, such as edges, lines and textural transitions. It is in general necessary to include structural detectors in the filtering process to delimit the neighbourhood on which the local statistics are estimated.

Let us take the scalar LMMSE filter of Kuan *et al* [1] as an example. The linear estimator $\hat{R}$ minimizing the mean square error $E[(R-\hat{R})^2]$ is given by

$$\hat{R} = aI + (1-a)\mu_R, \ \ 0 < a < 1. \tag{1}$$

The local mean reflectivity μ_R is estimated by the local mean intensity $\hat{\mu}_I$. The parameter a is a function of the local coefficient of variation σ_I/μ_I: The higher the local heterogeneity, the closer $\hat{R}$ is to I, *ie* the weaker is the smoothing. In a zone of constant reflectivity, the coefficient of variation is related to the equivalent number of looks L by

$$\sigma_I/\mu_I = 1/\sqrt{L}. \tag{2}$$

If $\hat{\sigma}_I/\hat{\mu}_I \leq (1+\epsilon)/\sqrt{L}$, the variations in the neighbourhood may be due entirely to speckle, and the neighbourhood is said to be Gamma-homogeneous. In this case it is reasonable to override (1) and merely set $\hat{R} = \hat{\mu}_I$ [2].

Early versions of the adaptive speckle filters use a fixed size window centered on the pixel to be filtered, as shown in Fig. 1a). On one hand, a large window should be chosen to minimize the variance of the estimations of the local statistics. On the other hand, a large window size is likely to increase the local heterogeneity measure, so that the noise reduction gets weaker. Refined versions include local edge detection, realized by a set of directional masks, to improve the homogeneity of the zone on which the estimations are performed [3]. This method is illustrated in Fig. 1b). The limited number of masks and the sensibility of such local edge detectors to speckle set bounds to the efficacity of this method. A further improvement consists in letting the size of the window increase gradually in order to obtain maximum size Gamma-homogeneous neighbourhoods [4], but for simplicity this method will not be considered here.

REGION-BASED SPECKLE FILTERING

The presence of speckle makes the segmentation of SAR images extremely difficult. A hybrid segmentation technique [5], based on the Ratio Of Exponentially Weighted Averages (ROEWA) operator, the watershed algorithm and region merging, has nevertheless permitted us to obtain satisfactory segmentations of images composed of agricultural parcels without any prior filtering. Our idea is to use the statistics calculated on the entire region when filtering a given pixel, as shown in Fig. 1c). This approach is computationally efficient, as the statistics are not calculated for each pixel, but only once for each region. The segmentation can not be considered as perfect, even though it approaches a thematic partition in regions. It should also be

This study is a result of the cooperation between LIMA/ENSEEIHT and CESBIO on contract 833/CNES/94/1022/00.

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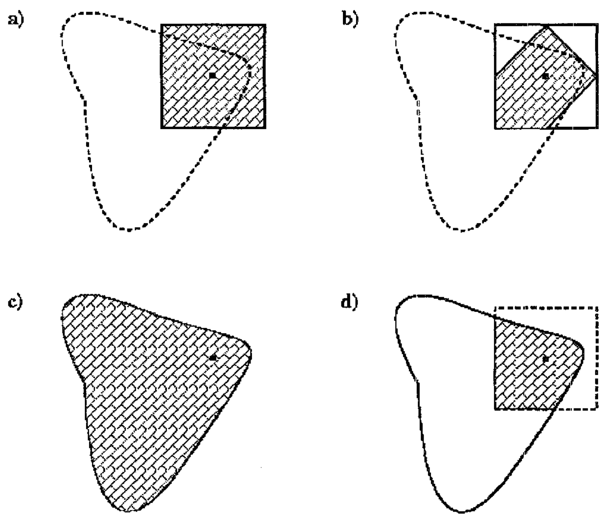

Figure 1: Neighbourhoods for the estimation of local statistics.

noted that thematic regions are not necessarily neither Gamma-homogeneous nor stationary. An intermediate solution, which is more robust to segmentation errors, is to base the estimations on those of the pixels of a fixed size window that belong to the same region as the central pixel, as shown in Fig. 1d).

COMPARISON

The four methods cited above have been tested on ERS1 images of an agricultural scene near Bourges, France. Fig. 2 shows an extract of a raw image and the segmentation obtained by the hybrid segmentation scheme. Fig. 3 shows the speckle reduced images obtained by the different versions of the scalar LMMSE filter. The size of the sliding window was set to 9×9. The version using a set of directional masks to detect edges [2] gives an important improvement compared to the classic version, particularly in preserving edges and other structures, but it introduces artefacts inside the different regions. This effect is greatly reduced when the statistics are calculated on entire regions, defined by a segmentation found prior to filtering. It should be stressed that the performance depends strongly on the segmentation. In our experience, a slight over-segmentation is to prefer, as details that are not represented in the segmentation will be degraded. This problem concerns fine structures as well as slow changes. The majority of the edges, which have been correctly detected, are well preserved. In the filtered image the transitions may actually appear too abrupt, owing to the fact that the edge pixels are attributed to one of the regions, even though they are generally mixed pixels, *ie* the response of elementary scatterers from both regions. The regions defined by the segmentation are in general much larger than a 9×9 window. This seems to increase the local heterogeneity and reduce the strength of the speckle filtering, especially in regions containing a very high number of pixels. The intermediate solution, using only those of the pixels of the region that lie inside a fixed size window, is less sensitive to segmentation errors and offers a better noise reduction at the cost of a higher computation time.

CONCLUSION

This region-based approach to speckle filtering is a computationally efficient way of reducing speckle while retaining significant edges. The segmentation method was developed for agricultural parcels, *ie* scenes composed of distinct regions of approximately constant reflectivity without neither texture nor relief. The edges that have been correctly identified by the segmentation are well preserved, but when we estimate the local statistics by regions, the speckle reduction is not as strong as for the method using directional masks. The intermediate version, using the segmentation in combination with a sliding window, offers a good compromize.

Further progress in SAR image segmentation would undoubtedly improve the results. In order to conserve thin linear structures, such as roads and rivers, appropriate structural detectors must be added. The same applies to transitions in texture. Artificial objects, where the speckle is not fully developed, should be identified and treated separately. The problem of too abrubt radiometric transitions at edges could be reduced by treating edge pixels in a special manner, *eg* using the local statistics estimated on both sides of the edge to compute a weighted average. Inspired by [4], the speckle reduction could be improved by combining the segmentation with a variable size window controlled by a stationarity criterion and guidelines on the minimum and maximum number of pixels.

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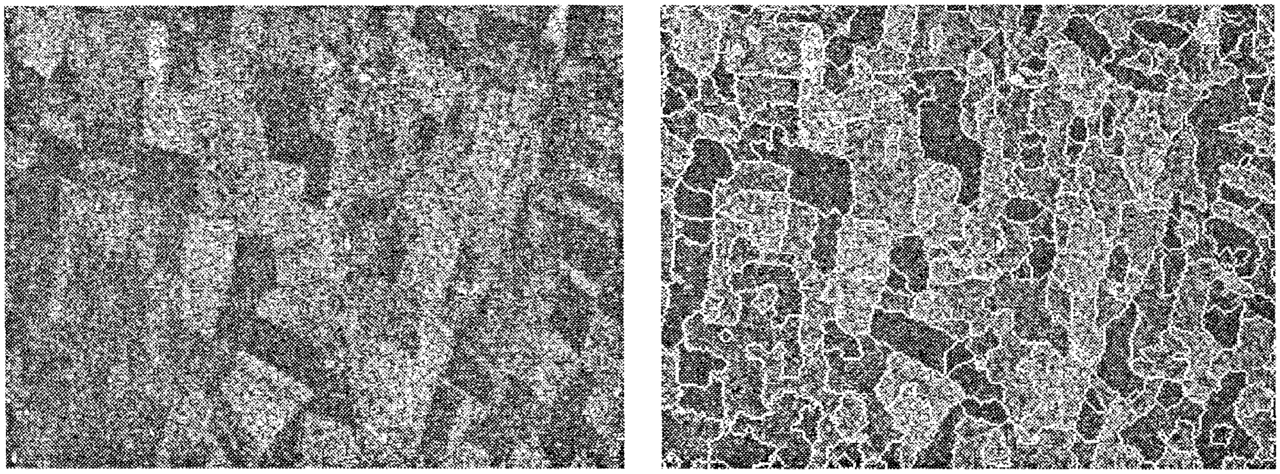

Figure 2: Extract of an amplitude SAR image from Bourges, France ©ESA - ERS1 data - 1993 (left) and its segmentation (right).

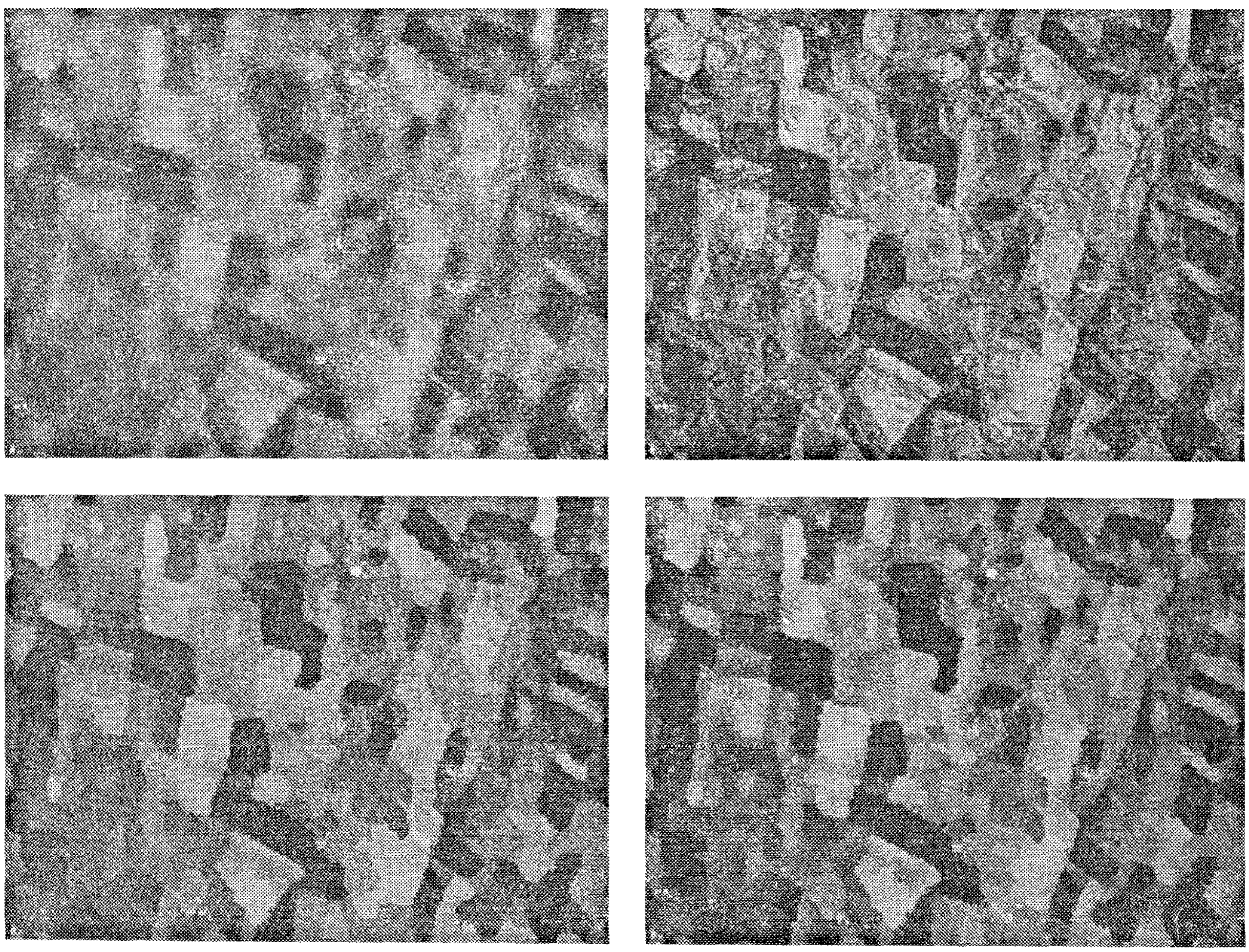

Figure 3: LMMSE filtered images: First row: using a sliding window (left) and a sliding window with edge detection (right). Second row: using the segmentation (left) and the segmentation in combination with a sliding window (right).