Homomorphic transformations for nonlinear adaptive filters

Vladimir V. Lukin, Alexander A. Zelensky, Victor I. Chemerovsky

Kharkov Aviation Institute, Department 507, 17 Chkalova Street,
310070, Kharkov, Ukraine, tel/fax (0572) 441186,
E-mail: lukin@xai.kharkov.ua

Abstract

For improvement of radar image quality their filtering is required. In case of intensive multiplicative noise with non-symmetrical distribution of speckle many filtering algorithms do not perform well. So here some new filtering techniques are proposed and tested. They are based on local adaptation principle and homomorphic transform use combined with application of nonlinear data processing methods. It is shown that by means of this an available trade-off of filter properties can be provided.

1. INTRODUCTION

The radar images are usually corrupted by intensive multiplicative noise, spikes can be present as well. The most noisy images are those ones formed by one-look synthetic aperture radars (SARs). The multiplicative noise in the considered case can be characterized by Rayleigh or one-side exponential probability density function (pdf) (depending upon SAR operation principle) both being non-symmetrical in respect to mean value.

In such situations the application of different linear filters to processing the radar images results in insufficient quality of output images. In order to overcome this problem many researches have developed nonlinear filters providing some benefits, in particular, the robustness in respect to spikes [1]. But it is difficult to get high efficiency of multiplicative noise suppression, good edge/detail preservation and reliable spikes removal simultaneously while using non-adaptive filters and applying them to initial data. That is why an approach based on the use of homomorphic transforms nonlinear data processing in the scanning window and local adaptation principles is put forward. It is shown that the application of direct homomorphic transform, nonlinear filtering and inverse homomorphic transform can sometimes lead to better suppression of multiplicative noise for image homogeneous regions. The performance of locally adaptive filters [2] depends upon proper selection of noise suppressing filters and local activity indicator. So the noise suppressing properties of homomorphic filters are analyzed. Only different nonlinear filters are considered because they are able to remove impulsive noise. Besides, a new adaptation parameter (trimmed local variance) for active areas detection is proposed and it occurred to be more sensitive to details with negative contrasts in respect to surrounding background and to detect edges more reliably in comparison to standard quasirange.

2. IMAGE/NOISE MODEL AND LOCALLY ADAPTIVE FILTERING

The most typical image/noise model for coherent one-look imaging systems is the following

$$I_{ij} = \begin{cases} \mu_{ij} I^t_{ij}, \text{ with probability } 1 - P_i \\ A_{ij}, \text{ with probability } P_i \end{cases}, \qquad (1)$$

where I_{ij} is the noisy image; μ_{ij} denotes the multiplicative noise (speckle) with the mean equal to unit and variance σ^2_μ; I^t_{ij} defines the true image; P_i is the probability of impulsive noise; A_{ij} denotes the value of spike for the *ij*-th pixel corrupted by it.

Depending upon the procedure of image formation (what is derived - the amplitude or intensity) the p.d.f. of μ can be the Rayleigh or one-side exponential ones, respectively

$$\rho(\mu) = \frac{\mu}{\sigma^2} exp(\frac{-\mu^2}{2\sigma^2}), \; \rho(\mu) = 0 \text{ for } \mu < 0 \qquad (2)$$

where σ is a parameter equal to 0.798, $\sigma^2_\mu = 0.273$;

$$\rho(\mu) = \lambda exp(-\lambda\mu), \; \rho(\mu) = 0 \text{ for } \mu < 0, \qquad (3)$$

where λ is a parameter equal to unit, $\sigma^2_\mu = 1$.

The next expression describes the "hard-switching" procedure of locally-adaptive filtering:

$$I^f_{ij} = \begin{cases} I^{pas}_{ij}, \text{ if } \eta_{ij} < \eta_t \\ I^{act}_{ij}, \text{ if } \eta_{ij} \geq \eta_t \end{cases}, \qquad (4)$$

where I^f_{ij} is the output of adaptive filter; I^{act}_{ij} and I^{pas}_{ij} denote the outputs of filters applied to "recognized" locally active (i.e. edges and fine details) and locally passive (homogeneous) areas respectively; η_{ij} is the used locally activity indicator; η_t defines the threshold.

It is known [3] that α-trimmed filters possess good multiplicative noise suppression efficiency for image homogeneous regions. The next expression describes α-trimmed filtering algorithm

$$I^f_{ij} = \frac{1}{q-p+1} \sum_{k=p}^{q} I^{(k)}_{ij}, \qquad (5)$$

where I^f_{ij} is the output of α-trimmed filter; *p*, *q* are the order statistic numbers; $I_{ij}^{(k)}$ is the k-th order statistic for the ij-th pixel for scanning window with aperture size N. The properties of modified α-trimmed filter [4] depend upon trimming factors α_1 and α_2 ($p=[\alpha_1 N]$, $q=[(1-\alpha_2)N]$; $\varepsilon^*=\alpha_2$) which define robustness to spikes and effect on edges blurring after filter application.

3. HOMOMORPHIC TRANSFORM NONLINEAR FILTERS

One idea of homomorphic transformation of an initial image is the transformation of data-dependant noise into additive one. Another idea described in this paper assumes the transformation of noise distribution into more suitable p.d.f. Here the "suitability" means providing of more efficient noise suppression for homogeneous regions of image. Procedure of noise suppression can be performed by any standard linear filter and nonlinear filter as well. After filtering the transformed image has to be restored with the help of inverse homomorphic transformation. It is worth to say that after such transformations and filtering an additional procedure of mean correction has to be carried out. For this aim the correction factor should be found using numerical simulation (test) data.

It is known that one-side exponential distribution can be got from Rayleigh one by following operation

$$I_{ij}^{e} = \left(I_{ij}^{r}\right)^2 \qquad (6)$$

where I_{ij}^{e} and I_{ij}^{r} correspond to image pixel with exponential and Rayleigh distributions respectively. Consequently, the square root operation defines the inverse homomorphic transform.

For image processing with homomorphic transformation we choose a modified α-trimmed filter with nonsymmetrical trimming factors which does not lead to output biasness [4]. In order to evaluate the degree of remainder fluctuations of noise after filtering we use the ratio between the variance σ^2 and the squared mean m derived for homogeneous regions

$$\sigma_O^2 = \sigma^2 / m^2 \qquad (7)$$

The results are presented in Table 1. The parameter $(\sigma_o^2)_h$ is used for homomorphic transform filtering.

Table 1

N	ε^*	(p, q)	σ_o^2	$(\sigma_o^2)_h$
3x3	0.1	(2,8)	0.0347	0.0323
	0.2	(4,7)	0.0384	0.0374
5x5	0.1	(5,22)	0.0129	0.0121
	0.2	(8,20)	0.0140	0.0135

4. PROPOSED LOCAL ACTIVITY INDICATORS

In paper [2] we introduced a new local activity indicator called trimmed local variance

$$(\sigma_{ij}^{t})^2 = \frac{1}{(q-p+1)(I_{ij}^{pas})^2\sigma_{\mu}^2}\sum_{r=p}^{q}(I_{ij}^{(r)} - I_{ij}^{pas})^2 , \qquad (7)$$

where I_{ij}^{pas} is the output value of the α-trimmed filter used for image homogeneous region processing. For multiplicative noise the quasirange should be derived as a ratio of $I_{ij}^{(q)}$ and $I_{ij}^{(p)}$, this provides more reliable detection of negative contrast details. Comparison of their performance (the upper for trimmed variance, the lower for quasirange, left Figures for initial images, right for transformed ones)is illustrated for test data for identical probability of false alarm. It is seen that trimmed variance performs a little better that quasirange and homomorphic transform leads to not worse results.

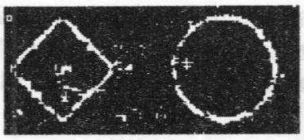
Fig.1,a

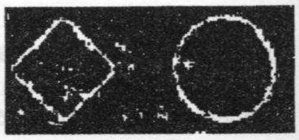
Fig.1,b


Fig.2,a


Fig.2,b

CONCLUSIONS

The proposed procedure of homomorphic transform filtering can provide better noise suppression efficiency and more reliable detection and preservation of edges and small elongated objects especially with negative contrast in respect to surrounding background.

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