# Speckle Noise Filtering in SAR Images by MAP Approach


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**Abstract.** The main purpose of this work is to study and implement the Maximum a Posteriori (MAP) filter to suppress speckle in SAR images. This type of noise is due to the coherent nature of the radiation used in Synthetic Aperture Radar and the interference between the waves reflected from the imaged area. This paper is based on the multiplicative model and considers several different densities to describe the "a priori" knowledge.


## 1 Introduction

SAR imaged areas are corrupted by speckle noise, which degrades images formed by laser beams, radar (SAR), ultrasound etc. Speckle is caused by the interference between waves reflected from microscopic scattering through the terrain, in the particular case of SAR images. This kind of noise can be modeled in terms of a random walk in the complex plane and, in the case of a large number of scatters within the resolution cell (fully developed speckle), the real and imaginary parts of the resulting complex field are Gaussian random variables . It has been experimentally verified in several works that over homogeneous areas, the standard deviation of the signal is proportional to its mean [Lee, (1981)]. This fact suggests the use of the multiplicative model for the speckle.

Kuan et all (1988) assumed the multiplicative model for the speckle, as well as one-look, quadratic detection and gaussian "a priori" density, to propose an adaptive non-linear pointwise filter that satisfies the MAP criterion. Lopes et all (1990) suggested a MAP filter that takes in account quadratic detection, gamma and beta distributions as "a priori" densities. The objective of this work is to investigate the performance of the MAP filter in order to reduce speckle noise in SAR images with one-look and linear detection using different "a priori" densities.

Firstly, we present the MAP estimator based on the multiplicative model of the speckle, using "a priori" gamma density. In section 3 there is a brief brief discussion about the results. The article concludes with remarks about future developments.

## 2 The Multiplicative Model and the MAP Estimator

The model used for the speckle is given by equation (1), where $z_{i,j}$ describes the amplitude of the noisy observed pixel in linear detection, $x_{i,j}$ is the original signal and $n_{i,j}$ is the noise with unitary mean. The indices $i$ and $j$ indicate the spatial position over the image.

$$z_{i,j} = x_{i,j}.n_{i,j} \tag{1}$$

As the detection is linear and the model assumed is multiplicative, the conditional probability density function is of type Rayleigh. The MAP estimate of $x$ is obtained by maximizing the "a posteriori" probability density function $f(x/z)$, which can be related to the "a priori" distribution through equation (2).

$$f(x/z) = \frac{f(z/x)f(x)}{f(z)} \tag{2}$$

Given the gamma "a priori" density

$$f(x) = \frac{\sigma}{\Gamma(\lambda)}(\sigma x)^{\lambda-1}e^{-\sigma x} \tag{3}$$

The MAP estimator is given by

$$2\sigma x^3 + x^2(6-2\lambda) - \pi z^2 = 0 \qquad (4)$$

where the parameters are estimated by the sample mean and the variance obtained from the multiplicative model

$$\begin{aligned} \hat{\mu}_x &= \hat{\mu}_z = m = \frac{1}{w}\sum_{i=1}^{w} z_i \\ \hat{\sigma}_x^2 &= \frac{\sigma_z^2 - \hat{\mu}_z^{\,2}.\sigma_n^2}{1+\sigma_n^2} \end{aligned} \qquad (5)$$

where w is the size of window around the pixel filtered and $\sigma_n^2$ is the noise variance. It is a constant according to the number of looks and the type of detection. The real and positive root of (4) whose value is between the mean and the observed pixel is taken as the filtered pixel value.

## 3 Results

Because the majority of pixels belong to homogeneous regions, the coefficients of variation, which can be expressed by $R=\sigma_X^2/\sigma_Z^2$, resulted negative, which indicates the presence of very homogeneous areas. In such cases the model based on the random walk fails and the central limit theorem does not hold because there are only one or two specular scatterers predominating [Nathan-Curlander (1987)]. The pixels that presented R<=0 were updated by the mean value, calculated in a 5x5 window centered at them. Otherwise, they were updated by the root of the filtering function between the mean and the observation.

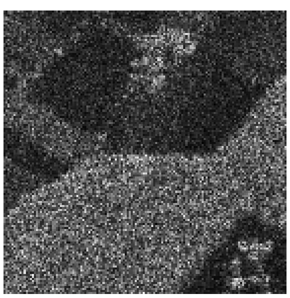

Figure 1. Original Image.

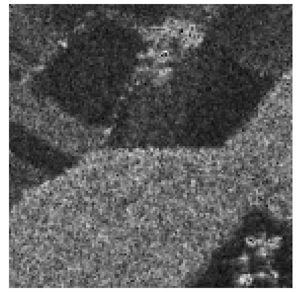

Figure 2.Filtered Image.

## 4 Further Developments

Future development will include other “a priori” densities leading to several alternative speckle reducing filters. Also, the clustering of the coefficients of variation [Li (1988)] will be taken as a subsidy for choosing the best window size for parameter estimation.


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## References


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