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# *Hierarchical Segmentation of Polarimetric SAR Images using Heterogeneous Clutter Models*

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## Abstract:

POLSAR images are generally modeled by a zero mean multivariate circular Gaussian distribution. Landcover backscatter characteristics are assumed homogeneous over the target area. However, thinner spatial features can be observed from the high resolution of newly available spaceborne and airborne SAR images. In this case, heterogeneous clutter models should be used because each resolution cell contains only a small number of scatterers.

To take this heterogeneity into account, the Spherically Invariant Random Vectors (SIRV) product model has been introduced. In the context of POLSAR data, the clutter is modeled as SIRV, a non-homogeneous Gaussian process with random power. The randomness is induced by variations of the radar backscattering over different polarization channels. Hence, the POLSAR target vector $\overrightarrow{k}$ is defined as the product between the independent complex Gaussian vector $\overrightarrow{z}$ with zero mean and covariance matrix $[M] = E\{\overrightarrow{z}\,\overrightarrow{z}^\dagger\}$ (representing the speckle) and the root of a positive random variable $\tau$ (representing the texture):

$$\overrightarrow{k} = \sqrt{\tau}\,\overrightarrow{z}, \tag{1}$$

where † denotes the conjugate transpose operator and $E\{...\}$ the mathematical expectation. It is important to notice that in the SIRV definition, the probability density function (PDF) of the texture random variable is not explicitly specified. As a consequence, SIRVs describe a whole class of stochastic processes. This class includes the conventional clutter models having Gaussian, K-distributed, Rayleigh or Weibull PDFs.

When using the SIRV product model, one can notice that the speckle presents a dual nature depending on the involved polarimetric descriptor:

- intensity texture descriptor: speckle can be considered as a nuisance parameter as the Gaussian kernel induces undesired spatial variations over the areas homogeneous in terms of texture,

- covariance matrix descriptor: speckle represents the useful signal as the covariance matrix is computed using the Gaussian kernel, while the texture appears as nuisance.

In Eq. 1, the covariance matrix is an unknown parameter which can be estimated from Maximum Likelihood (ML) theory [1]. Recently, a new estimation scheme for deriving normalized coherency matrices and the resulting estimated span with high resolution POLSAR images. The proposed approach couples nonlinear ML estimators with span driven adaptive neighborhoods [2] for taking the local scene heterogeneity into account. Two estimators are introduced for describing the POLSAR data set: the Fixed Point estimator of normalized coherency matrix and the corresponding LLMMSE span. The Fixed Point estimation is independent on the span PDF and represents an approximate ML estimator for a large class of stochastic processes obeying the SIRV model. Moreover, the derived normalized coherency is asymptotically Gaussian distributed.

In this paper, we propose to apply the SIRV estimation scheme in the hierarchical segmentation algorithm from [3]. This algorithm is based on the maximization of the SIRV log-likelihood function. At each iteration, the two 4-connex segments which minimizes the decrease of the log-likelihood function are merged. This step is repeated iteratively until the required number of segments is reached.

To model the estimated texture parameter, we propose to use the Fisher PDF. This PDF can be viewed as a generalization of a Gamma PDF by an Inverse Gamma PDF. Therefore, its hybrid behaviour between an heavy head and an heavy tail PDF is well adapted to fit different type of scene. For a Fisher distributed texture, authors show that the target vector $k$ follows a KummerU PDF and use this PDF in the hierarchical segmentation algorithm [4]. Segmentation results are shown on both simulated and high resolution POLSAR data.

## References


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