NOISE VARIANCE ESTIMATION OF SAR IMAGE IN LOG DOMAIN

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Abstract: Since variance of noise is important parameter for a noise filter to reduce noise in image and the performance of noise filter is dependent on estimated variance. In this paper, we apply additive noise variance estimation method to estimate variance of speckle noise of synthetic aperture radar (SAR) imagery. Generally, speckle noise is in multiplicative model, logarithmic transformation is then used to transform multiplicative model into additive model. Here, speckle noise is generally modeled as Gamma distribution function with different looks. The additive noise variance estimation is processed in log domain. The synthesis image and real image of SAR are implemented to test and confirm results and show that more accurate estimation can be achieved.

Keywords: Speckle Noise Estimation, SAR Imagery.

1. Introduction

Normally, the noise variance is estimated by a given variance in homogeneous area because of that variance of signal in homogeneous area is of zero, nearly. As mentioned criterion, the estimated variance derived from [1] is used for indicating the homogeneous area. Since such the given variance is based on that pdf of noise is Gaussian with zero mean. Really, such assumption is exact for multilook SAR imagery such as the number of looks more than 10 looks at which pdf of noise is reached to Gaussian with zero more and more. For single look imagery and number of looks less than 10 looks, the estimated variance is achieved not more accuracy enough. In this paper, we propose a way to refine the estimated one, namely the refined-estimated one, more accuracy based on maximum standard deviation to mean.

This paper is organized as follows. In Section 2, statistics of speckle in log-domain is briefly described to derive formula for computing the estimated variance. In Section 3, the homogeneity analysis in log-domain for indicating the number of homogeneous areas is described. The experimental results and conclusion are achieved in Section 4 and 5, respectively.

2. Statistics of Speckle in Log Domain

Recently, most of filters are excellently designed based on additive Gaussian noise with zero mean and any variance but in SAR imagery, it is degraded by speckle noise caused by the illumination by the coherent radar. In general, speckle noise is described as a multiplicative model with unit mean and any variance dependent on number of looks (L). In this paper, we address to employ a designed method based on additive noise model to estimate speckle noise for single and multilook SAR imagery. First we review statistical properties of speckle noise in intensity format only on logarithmic domain after employed logarithmic transformation convert the multiplicative speckle model into an additive noise model [1]. Let X denote the desired pixel reflectivity and Y be the observed image as gray level and assume that speckled image represents an average of L looks (independent samples or pixels). The original multiplicative model is

$$Y = XN \tag{1}$$

where N is the speckle noise in the intensity image, following a Gamma distribution with unit mean and variance $1/L$. Taking natural logarithm (1)

$$\tilde{Y} = \tilde{X} + \tilde{N} \tag{2}$$

where $\tilde{Y} = \ln(Y)$, $\tilde{N} = \ln(N)$ and $\tilde{X} = \ln(X)$.

Following as [1], The mean and variance of noise $\tilde{N}$ in the additive model corresponding with those of speckle N in the multiplicative model of L looks can be computed to approximate them in log-domain.

The mean is given by

$$E(\tilde{N}) = \psi(L) - \ln(L), \quad \psi(1) = -C \tag{3}$$

where $\psi(\cdot)$ is the Digamma function. In case of L being integer, (3) is rewritten as

$$E(\tilde{N}) = \bar{n} = \sum_{m=1}^{L-1} \frac{1}{m} + \psi(1) - \ln(L), \quad \psi(1) = -C \tag{4}$$

where C is Euler's constant $(C = 0.577215)$. The variance is given by

$$\mathrm{var}(\tilde{N}) = \sigma_n^2 = \psi(1,1) - \sum_{m=1}^{L-1} \frac{1}{m^2}, \quad \psi(1,1) = \frac{\pi^2}{6} \tag{5}$$

3. Homogeneity Analysis in Log-Domain

In general consideration of SAR imagery, the terrain reflectivity can be classified in two classes. One of them is the homogeneous class corresponding with the area where given pixel image x is constant. Others is the heterogeneous class corresponding with the area where given pixel image x varies. In fact that a speckled image filtering in the homogeneous area requires widen window size than that in heterogeneous area to filter out the noise more and more possible while edge preserving is necessary in heterogeneous area, the smaller window size is then required. In order to adapt window size during filtering process for homogeneity analysis in logarithmic domain, selected area between homogeneous and heterogeneous area is derived. From the additive noise model in (2), let $\tilde{Y} = y, \tilde{N} = n$, and $\tilde{X} = x$ then

$$y = x + n \tag{6}$$

The mean of y is

$$\bar{y} = \bar{x} + \bar{n} = \bar{x} \quad ; \bar{n} = 0 \tag{7}$$

and the variance of y is

$$\begin{aligned} \sigma_y^2 &= E[(y - \bar{y})^2] \\ &= E[x^2] + E[n^2] - \bar{y}^2 \end{aligned} \tag{8}$$

For homogeneous area [2], the average intensity of terrain reflectivity is constant, then $E[x^2] = \bar{x}^2$ thus

$$\sigma_y^2 = \bar{x}^2 + E[n^2] - \bar{y}^2 = E[n^2] = \sigma_n^2 \tag{9}$$

On the other hand, for heterogeneous area [2], average intensity of terrain reflectivity varies, from (8) we obtain that

$$\sigma_y^2 > \sigma_n^2 \tag{10}$$

4. Experimental Results

To evaluate the proposed way to refine the estimated variance, both speckled synthesis and real SAR image are used to test and confirm results.

1) Speckled Synthesis Image

Standard image Lena of 512×512 sizes shown in Fig. 1 is multiplied by multiplicative noise as Gamma distribution with unit mean and any variance of L looks. Fig. 2(a), (b), (c) and (d) show the speckled synthesis image for 1, 2, 4 and 8 looks. Numerical results are indicated in Tables 1, upper parts. For any variance, the number of the refined-estimated variances based on the maximum standard deviation to mean (std/m) corresponding with window sizes of 10 by 10 are compared with the estimated one given from (5) seeing that the given refined-estimated one is more accuracy.

2). Real SAR Image

The real SAR image from [3] which is of a 300×300 Ku-band SAR image shown in Fig. 3 is used to test and confirm result. Number of looks is of 4 looks. Numerical result is shown in Table 1, lower parts as the speckled synthesis image style. Since, in case of real image, the exact noise variance does not know, the refined-estimated variance is then confirmed that more accuracy than the estimated one from (5) based on results from the speckled synthesis image, that is, the refined-estimated variance must always be lower than the estimated one.

5. Conclusions

As such the proposed way to refine the estimated variance for the single look imagery and multilook one less than 10 looks, the refined estimated variance can be achieved more accuracy, particular in the single look imagery at which the estimated one is most of error. Even though, such variance is not most accuracy but it is still more accuracy than the estimated one always.

References

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Fig. 1 Original image (standard Lena image)

(a)

(b)

(c)

(d)

Fig. 2 Speckled synthesis image (a), (b), (c) and (d) of 1, 2, 4 and 8 looks, respectively.

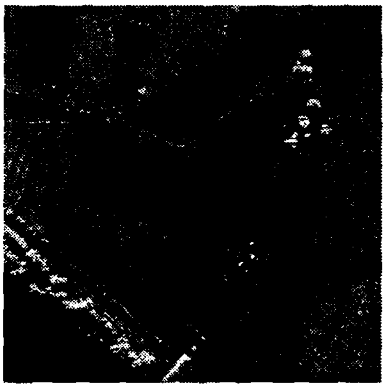

Fig. 3 SAR image

Table 1 Estimating noise variance for the synthesis and real image.

No of Looks	Exact Var.	Est. Var. (5)	Error	Refined Est. Var.	Error	Window sizes	std/m
Synthesis							
1	1.0000	1.6449	-0.64490	0.8114	+0.18860	10 by 10	0.2029
2	0.5000	0.6449	-0.14490	0.5628	-0.06280	10 by 10	0.1819
4	0.2500	0.2838	-0.03380	0.2780	-0.02800	10 by 10	0.1390
8	0.1250	0.1331	-0.00810	0.1264	-0.00140	10 by 10	0.0955
Real							
4	-	0.2838	-	0.2557	-	10 by 10	0.3640