Quantitative Dual Nature Analysis of Mean Square Error in SAR Image Despeckling

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***Abstract*---The despeckling of Synthetic Aperture Radar (SAR) images is a critical task. There are certain assessment parameters to judge the algorithm. The article experimentally analyses the dual and diverse nature of Mean Square Error (MSE) in SAR image despeckling. This dual nature is investigated in two different situations. *Case 1:* when the despeckled SAR image is compared with speckle free SAR image. *Case 2:* when despeckled SAR image is compared with real speckled SAR image. In both these cases, the comparative statistics of the MSE is different. In case 1, the MSE should be low for better image quality and higher Peak Signal to Noise Ratio (PSNR) and in case 2, MSE must be high for significant speckle reduction. This analysis will help the researchers to use the MSE as performance metric in both these above cases. MSE is a valuable metric in despeckling.**

***Keywords*--**MSE, SAR Image despeckling, PSNR.

I. INTRODUCTION

The despeckling operation is performed in two cases: with reference indexes and without reference indexes. The mainly used assessment parameters in case 1 are Structural Similarity Index Measurement (SSIM), Signal to Noise Ratio (SNR), Mean Square Error (MSE), PSNR, Energy Signal-to-Noise Ratio (ESNR), Universal Image Quality Index (UIQI), Feature Similarity Index Metric (FSIM), Edge Correlation (EC) and Pratt's Figure Of Merit (FOM) [1]. The assessment parameters mainly used in case 2 are Equivalent Number of Look (ENL), Coefficient of Variation (CV), Target–to–Clutter Ratio (TCR), Noise Variance (NV), deflection ratio and ratio images [1]. The analysis in this article emphasizes on using MSE in both the above cases. It shows great usability in assessing the performance of the despeckling algorithm.

The MSE is the commonly used metric in the image denoising. MSE depends intensely on the image intensity scaling. Let I_1 and I_2 are the two images of size M×N, respectively representing the I_1- channel frame of reference image and I_2- channel frame of the denoised image. The mean square error between the two images is given in the Eq 1. The more I_1 is similar to I_2, the more MSE is small. The utmost resemblance is reached when MSE equivalent to 0. It is seen in the experimental observation that when original reference image is available then smaller MSE value is considered as best value. When denoising operation is performed on real noisy images then higher MSE values are considered as best values. Ashkan Masoomi, Roozbeh Hamzehyan, and Najmeh Cheraghi Shirazi [6] experimented a work with the observation of without reference indexes, where they observed high MSE values shows better results. The same observation is analyzed by M. Mastriani in [2]. The experimental analysis is performed in the next section over two articles [3], [6].

The organisation of the article is as follows. Section 2 analyses the dual nature of MSE in SAR image despeckling and Section 3 concludes the article.

II. EXPERIMENTAL ANALYSIS

Case 1: Original speckle free SAR image available, when despeckled SAR image is compared with speckle free SAR image.

MSE and PSNR are the two major error detection metrics for image quality comparison. MSE represents the cumulative squared difference between despeckled and original SAR image. PSNR depicts the peak error [4]. The lower value of MSE, lower is the error.

$$MSE = \frac{1}{M \times N} \sum_{M,N} [I_1(m,n) - I_2(m,n)]^2 \quad (1)$$

m, n are rows and column of the input SAR image.

$$PSNR = 10 \log_{10}\left(\frac{R^2}{MSE}\right) \quad (2)$$

R is the maximum pixel value of the input SAR image. The PSNR should be comparatively high for the best image quality results.

According to the equation 2,

$$PSNR \propto \frac{1}{MSE} \quad (3)$$

PSNR is inversely proportional to MSE. The high is the PSNR, low is the MSE for best image quality results. It concludes that in case 1, MSE must be comparatively low among other filtering techniques for being best despeckling algorithm [5].

Theoretically, MSE is the average squared difference between speckle free original SAR image and despeckled SAR image. If this cumulative difference is big, then the final despeckled image is far different from original image which results to weak algorithm. If the cumulative difference is small, then the pixel statistics of the despeckled image is close to original image which results to strong and efficient algorithm.

Case 2: Real speckled SAR image available, when despeckled SAR image is compared with real speckled SAR image.

In case 2, MSE indicates the average squared difference between despeckled and real speckled SAR image. The comparatively small MSE value shows the smaller difference between despeckled and real speckled SAR image which depicts less reduction of speckle noise i.e. weak algorithm.

The comparatively high MSE indicates the greater difference despeckled and real speckled SAR image, which means that there is a significant speckle reduction [2]. In case 2, it is extremely necessary to be very careful with the edge and region preservation.

TABLE 1. MSE VALUE COMPARISON OF X5 WITH OTHER FILTERING TECHNIQUES FOR BEST QUANTITATIVE RESULTS IN TWO DIFFERENT CASES: CASE 1 AND CASE 2. Σ =SPECKLE NOISE VARIANCE.

Filtering Techniques	MSE	
	CASE 1 Speckle noise added to SAR image say, (σ=20)	CASE 2 Real speckled SAR image
X1	C1	D1
X2	C2	D2
X3	C3	D3
X4	C4	D4
X5	**C5**	**D5**

Assumption: X5 is the proposed method, which is compared with the four other standard methods [X1, X2, X3 and X4] for best image quality results using MSE metric.

According to the above analytical study, X5 performs best for below results,

$$CASE\ 1\text{: } [C5] < [C1, C2, C3, C4]$$

$$CASE\ 2\text{: } [D5] > [D1, D2, D3, D4]$$

For the best despeckling results of X5 algorithm, C5 should be minimum and D5 should be maximum [3].

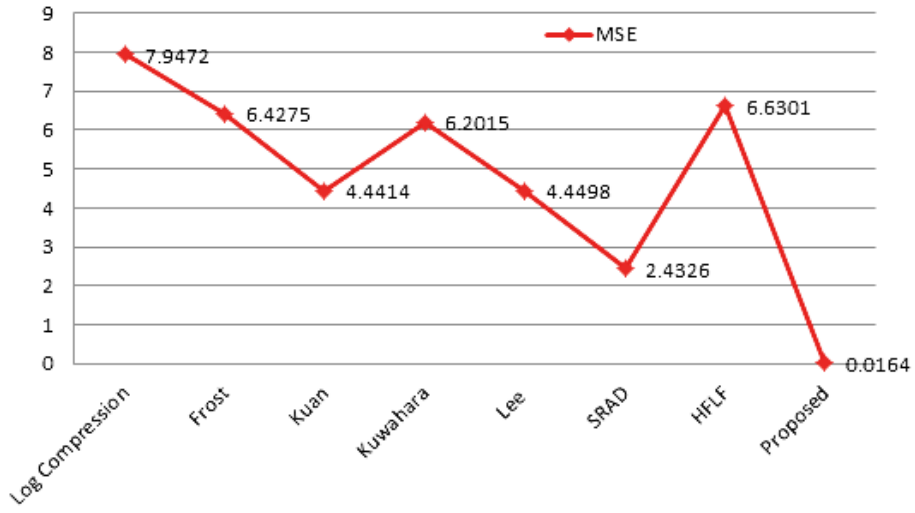

Fig 1. MSE results of article [3].

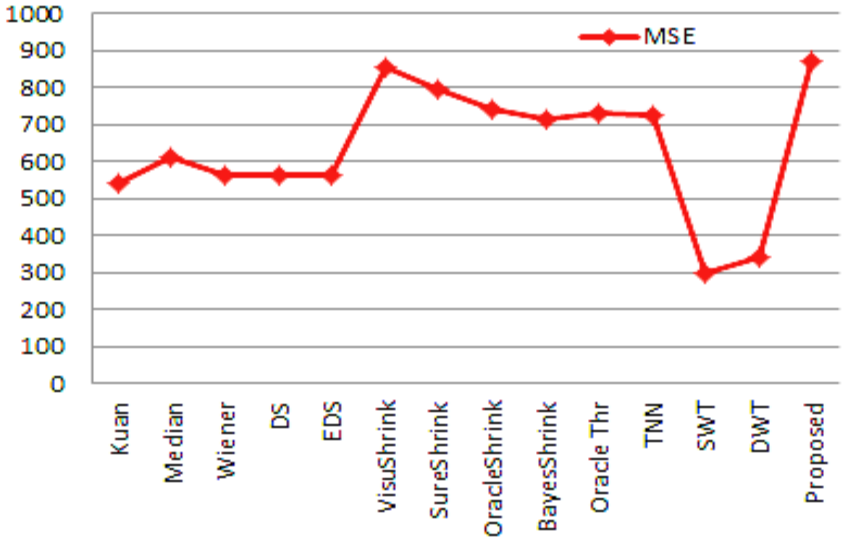

Fig 2. MSE results of article [6].

The above experimental analysis verifies the dual nature of MSE metric. In fig 1, the best results are obtained at minimum MSE values in the case of simulated speckled SAR image while in the fig 2, the best results are obtained at maximum MSE values in the case of real speckled SAR image.

III. Conclusion

There are certain selected performance measures for the full reference and no reference indexes, out of them; MSE is chosen to be the only metric to be used for performance evaluation in both the cases. MSE is a valuable metric. Its dual nature in different situations validates its importance of its use. This article clears the air of confusion of using MSE in case 2. Its diversity is the real strength. It can be easily used in either case.

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