Wavelet Filtering of Speckle Noise - Some Numerical Results

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Abstract

We present our most recent results about an ongoing study addressing the comparison of various speckle reduction filters. In a previous work, we have concentrated on the best Signal-to-Mean-Square-Error (S/MSE) ratio provided by a complex Wavelet Coefficient Shrinkage (WCS) filter and several standard speckle filters. Here we specifically address the numerical behavior of the WCS filter over a change (1) in the regularity and type of the wavelet (orthogonal versus bi-orthogonal) and (2) in the wavelet coefficient thresholding type (soft- versus hard-thresholding). We also present measures of the variation of the S/MSE over a wide range of the WCS filter parameters in order to provide information on the optimal application range of the filter in practical situations. As in our previous work, tests are performed on optical imagery with a simulated multiplicative Log-Normal noise. The S/MSE ratio is measured after averaging the filtered images over 16 diagonal shifts of the Discrete Wavelet Transform (DWT) in order to approximate a shift invariant DWT. Our experiments show, among other, that the optimal threshold level depends on the spectral content of the image and that the soft-thresholding scheme is the best choice for images with high spectral content.

1 Introduction

The aim of this paper is to present recent results about an ongoing study addressing the comparison of various speckle reduction filters. In previous works [1, 2], we have concentrated on the best Signal-to-Mean-Square-Error (S/MSE) ratio provided by a complex Wavelet Coefficient Shrinkage (WCS) filter and several standard speckle filters that are widely used in the radar imaging community (Lee, Kuan, Frost, Geometric, AFS, Gamma and Oddy). It has resulted that the complex WCS filter was among the best ones, quantitatively and qualitatively. In particular, the filter was clearly outperforming the standard ones for images with large speckle noise; up to 10% improvement on a low spectral content image.

In the current work, we specifically address the numerical behavior of the WCS filter over a change (1) in the regularity and type of the wavelet (orthogonal versus bi-orthogonal) and (2) in the wavelet coefficient thresholding type (soft- versus hard-thresholding). In addition, we found very much instructive to measure the variation of S/MSE over a wide range of the complex WCS filter parameters, because it provides much information on the optimal application of the filter in practical situations.

The paper is organized as follows. In the next subsections, we provide some background about speckle statistics and the measure we use to quantify the filtering process. In Section 2, we describe the filters we are comparing in this report. Section 3 presents a comparative results, in tables and graphics form, for 2 standard filters and the WCS filter with various wavelets (complex orthogonal and bi-orthogonal) and thresholding procedures. A brief wrap-up is given in Section 4.

1.1 Speckle

Speckle noise is a common phenomena in all coherent imaging systems like laser, acoustic and SAR imagery. The source of this noise is attributed to random interference between the coherent returns.

Fully developed speckle has the characteristics of a random multiplicative noise. Theoretically, under the assumption that the real and imaginary parts of the speckle signal have zero-mean Gaussian density, speckle intensity can be shown to follow a Gamma distribution [3]. Experimental speckle distributions can deviate from the theoretical Gamma distribution. For instance, Log-Normal distribution satisfying

$$X_{Log-Normal} = m \exp\left(X_{Normal}\sqrt{2\log(M/m)}\right)$$

where $M$and m are the mean and median values and