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Speckle Suppression in Medical Ultrasound Images through Schur Decomposition

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Abstract: A technique based on Schur decomposition to supress the multiplicative (speckle) noise from medical ultrasound images is presented in this paper. An image which carries the speckle noise is divided into small overlapping segments, size of these segments depends on the nature of speckle carried by the image and a global covariance matrix is calculated for the whole image by averaging the covariances of all segments. The global covariance matrix is decomposed through Schur decomposition to obtain the orthogonal vectors. A subset of these orthogonal vectors that correspond to largest magnitudes of eigenvalues are selected to filter out the speckle noise from the image. The proposed approach is compared with four benchmark filtering techniques, Homomorphic Wavelet Despeckling (HWDS), Wiener, Frost and Gamma. Two types of simulated ultrasound image and five types of real ultrasound images of Fetal neck, Left Kidney, Right Kidney, Musculo skeletal nerve and Lymph Node are tested. The proposed approach performed maximum suppression of speckle noise in all types of the images with optimal resolution and edge detection. The despeckling performance of the proposed approach is even better compared with the benchmark schemes once the speckle noise is rough, which is usually the case for soft tissue.

1. Introduction

Medical imaging gained more and more importance with the advent of powerful computing devices and enhanced image processing techniques. Medical ultrasound plays an important role in the medical field for diagnosing different diseases [1]. It is non-invasive and cost effective real-time imaging modality that produces images of body's internal organs by transmitting high frequency sound beams into the body and by collecting their corresponding reflected echoes [2].

Ultrasound medical images inherit intricate problem of speckle noise due to interference of randomly generated ultrasound pulses. Speckle noise is spatial correlated multiplicative in nature with granular appearance caused by the inference of various signals reflected from the scattered waves within a resolution cell [3][4]. The effectiveness of the ultrasound image depends upon the quality of the image and absence of the speckle noise [5]. Therefore, speckle noise removal is an important signal processing task in ultrasound imaging.

Different denoising methods were proposed in literature such as Wiener Filter, HWDS, Frost Filter and Gamma Filter [6]. William K. Pratt [7] proposed Wiener filtering method based on the statistical estimation of an unknown signal with poor signal-to-noise (SNR). Comparatively to the deterministic filters, Wiener filter uses spatial properties of the original signals and widely used for image denoising. When speckle noise is encountered, Wavelet shrinkage techniques pre-process the speckled image by homomorphic transformation, and thus called Homomorphic Wavelet Despeckling (HWDS) techniques [8]. The experiments show that HWDS does not enhance the SNR because the speckle coefficients are larger than the threshold value in Ultrasound images [9]. Gamma filter is a low pass special filter which preserves the image details based on the individual pixel grey level value and its surrounding window pixels [6]. Adaptive filters are generally used in image processing with the assumption that speckle noise is strictly multiplicative, e.g. Frost's filter [10]. Frost filter works based on local statistical model. Filter parameters are adjusted according to the local area statistics of the target pixel. It acts as mean filter depending on uniform regions that tend to be smoothed and speckle noise is removed by retaining high contrast edges and their signal values [11]. Chengbin and Kaifu proposed switching median based denoising method where only noisy pixels are updated while noise free pixels remains unchanged [12]. Alex et al. proposed speckle reduction and smoothing method based on selective average filters which are adjustable [13].

In this research study, a new Schur based technique for denoising ultrasound images is introduced. Schur decomposition is one of the applications of linear algebra [14]. This research article is structured as follows; in section II Schur theorem is explained. In section III ultrasound signal model and the image quality measures are presented respectively. Section IV presents the despeckling algorithm based on Schur method. Section V confer to the results of the algorithm applied to simulated as well as to real ultrasound images. Section VI concludes the paper.

2. Schur Theorem

For a given matrix M of size $n \times n$ there exists a unitary matrix U such that $U \times M$, U is upper triangular with diagonals having eigenvalues which is called Schur form