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Original research article

Reduction of speckle noise ultrasound images based on TV regularization and modified bayes shrink techniques

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ABSTRACT

A challenge for the researchers in medical ultrasound images is speckle noise reduction. In our work, we introduced a new method which reduces speckle noise in ultrasound images. Our method is based on TV regularization and modified bayes shrink. First, TV regularization is performed on the ultrasound image. Then, we perform a discrete wavelet transform on the coefficients obtained from total variation. Some subbands involving an approximation subband and detail subbands are revealed in output. Afterward, modified bayes shrink and soft thresholding are performed on the coefficients of the detail subbands whereas keeping the coefficients of the approximation fixed. Finally, invert the wavelet transform to retrieve the image. The performance of the algorithm has been tested using quantitative measures on synthetic and real ultrasound images. Experiments show that the proposed method does remove speckle noise significantly.

1. Introduction

During the past two decades, Ultrasound imaging is often preferred over other medical imaging modalities because it is noninvasive, portable, versatile; it is relatively low-cost. These properties make ultrasound imaging the most prevalent diagnostic tool in nearly all hospitals around the world.

An inherent characteristic of coherent imaging, including ultrasound imaging, is the presence of speckle

noise. This type of noise is an inherent property of medical ultrasound imaging and because of this noise the image resolution and contrast become reduced, which affects the diagnostic value of this imaging modality. Speckle arises when coherent light is reflected from a rough screen and observed by an intensity detector with a finite aperture. Speckle has the characteristics of random multiplicative noise in the sense that the noise level increases with the average gray level of a local area. It is a random, deterministic, interference pattern in an image formed with coherent radiation of a medium including high numbers of scatterers [11]. Speckle noise leads to produce fine-false structures that decrease contrast of image and wrapping the actual boundaries of the tissue. Therefore, developing methods to reduce the speckle contrast is the key to make the ultrasound image a favorable source. The algorithms of speckle reduction should enhance the signal to noise ratio, while conserving the edges and lines in images.

In the past few years, numerous adaptive filters have been proposed. Among the best known are the Lee [12], the Kuan [13], the Frost [14], and the modified Lee and modified Frost filters [15]. These methods are far from being an optimal tool

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for suppressing speckle noise because it tends to reduce noise at the expense of overly smoothing the image. Additionally, the image further suffers from the loss of important details, such as texture patterns, due to blurring.

Nonlinear diffusion filter [16] is a nonlinear filter. In order to control the direction and strength diffusion, the edge detection function has been used. This method removes speckle noise and preserves the edge of the image at the same time. After Mallat introduced the idea wavelet transform and fast wavelet decomposition methods [17], the use of multiscale methods for noise removal has attracted the researcher [18–21]. In [22], a method is proposed based on fractional Fourier transform for speckle reduction. The multiscale nonlinear processing method by Hao et al. [23], and the Bayesian wavelet method by Achim et al. [24] were proposed. In [25], an algorithm is presented based on multiscale nonlinear wavelet diffusion for speckle suppression and edge enhancement. At first, apply dyadic wavelet transform for image. Then, diffusion

function is calculated based on the modulus of wavelet coefficients. Afterward, wavelet diffusion is done by adjusting the coefficients at each scale with the diffusion function. Finally, perform inverse wavelet transform to reconstruct the image. In [26], A method is presented based on adaptive weighted total variation. At first, model of speckle noise is determined in ultrasound images. Then, an adaptive window is selected that shapes, sizes and orientation change with the image structure. The edge area is determined based on adaptive window. Finally, speckle reduction is performed in homogenous areas and any noise removing is performed in the edge regions of the image.

In [3], a combination of wavelet and curvelet transforms is used to decrease the speckle noise in SAR images.

In [4], at first, 2-dimentions wavelet decomposition is applied to log transformed Optical Coherence Tomography images. Then, the coefficients for all subband are calculated. Finally, invert the wavelet transform to reconstruct the image.

In [6], a combination of blind source separation and the fractional fourier transform is used for speckle reduction in medical images.

This paper is organized as follows: In Section 2, proposes a new algorithm for speckle reduction that is combination TV Regularization, and modified bayes shrink. In section 3, Experimental results and discussion are represented and Section 4 concludes the paper.

2. Proposed method

A generalized model of the speckle imaging is given by:

$$g_{r,s} = f_{r,s} n_{r,s} + v_{r,s} \tag{1}$$

Where $f_{r,s}$indicates the signal or reflectivity without noise, $g_{r,s}$ is the noisy pixel in the center of the moving kernel, $n_{r,s}$ and $v_{r,s}$ indicate the speckle and additive noise, respectively, and r,s indicate the spatial coordinates of the image.

In the present work, two techniques, namely, TV Regularization, and modified bayes shrink are combined to form a model for Reduction of Speckle noise ultrasound images.

The main steps of the proposed despeckling algorithm can be represented by the block diagram as shown in Fig. 1.

These techniques are explained below.

The TV Regularization has become a well-established technique for modeling a class of image processing problems [7–10,27,29]. The method is based on the total variation (TV) minimization for image denoising due to Rudin-Osher-Fatemi [10,30]. TV model tries to solve the variation problem

$$\min \ in\ z : \quad \alpha \int_{\omega} |g - z|^2 dxdy + \int_{\omega} |\partial z| dxdy \tag{2}$$

Where g is noisy image and $\alpha > 0$ is a scaling function. The associated Euler-Lagrange equation of the Rudin-Osher-Fatemi model formally is

$$\left\{ \begin{array}{l} z = g + \dfrac{1}{2\alpha} div(\dfrac{\nabla z}{|\nabla z|}) \quad in\ \omega \\ \dfrac{\partial z}{\partial n} = 0 \quad on\ \partial\omega \end{array} \right. \tag{3}$$

A difficulty with $\int_{\omega} |\partial z| dxdy$is that it has a derivative singularity when z is locally constant. To avoid this, a small parameter $\varepsilon > 0$ is added within the square root

$\min \ in\ z : \quad \alpha \int_{\omega} |g - z|^2 dxdy + \int_{\omega} \sqrt{\varepsilon^2 + |\partial z|^2} dxdy$ (4)

Then, the Euler-Lagrange equation minimization is:

$$\left\{ \begin{array}{l} z = g + \dfrac{1}{2\alpha} div(\dfrac{\nabla z}{\sqrt{\varepsilon^2 + |\partial z|^2}}) \quad in\ \omega \\ \dfrac{\partial z}{\partial n} = 0 \quad on\ \partial\omega \end{array} \right. \tag{5}$$