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Speckle reduction in breast cancer ultrasound images by using homogeneity modified bayes shrink

Iman Elyasi [a,*], Mohammad Ali Pourmina [a], Mohammad-Shahram Moin [b]

[a] *Electrical and Computer Engineering Department, Islamic Azad University, Science and Research Branch, Tehran, Iran*
[b] *IT Faculty, ICT Research Institute, Tehran, Iran*

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ABSTRACT

Ultrasound imaging suffers from severe artifacts caused by speckle noise. The paper introduces an algorithm for speckle noise reduction in breast cancer ultrasound images. Based on wavelet analysis and filtering, we employed a combination of homogeneity filtering and modified bayes shrink methods to remove noise while keeping the sharpness of important features. First, we replace pixel intensity by the mean of homogenous neighborhood and then, the threshold value of modified bayes shrink is employed to distinguish homogenous regions from regions with speckle noise obtained from homogeneity filtering. The proposed algorithm is called Homogeneity Modified Bayes Shrink (HMBS). A comparative study with other despeckling methods, using quantitative indices, showed the superiority of the proposed method over those methods.

1. Introduction

One of the most common cancers in women is breast cancer, and about one of the 8 women (in different societies) diagnosed with breast cancer. Breast cancer leads to produce malignant (carcinogenic) cells in breast tissues. The history of person health effects on developing rate to breast cancer. Different risk factors lead to breast cancer, such as: early age at menarche, first delivery in old ages or non-delivery, previous history of invasive breast cancer, obesity, inactivity, alcohol, white strain and family background of breast cancer in first degree relatives. However, having these effects does not suggest that a person will be diagnosed with breast cancer and also not having these effects does not suggest that the person will be diagnosed with breast cancer.

The probability of developing invasive breast cancer in women is not the same at different age intervals [1]. According to study [2], early detection of breast cancer is very important and can contribute to up to 40% decrease in mortality rate. One of the most important tools for early detection of breast cancer is the use of imaging methods.

In the past, the mammography has been the most widely used screening modality, however, due to some limitations, its application is dropping. Low quality detection of mammography leads to high rate of nonessential biopsies that were not necessary (about 65–85%) [3]. It also has a high false-negative rate [4]. The nonessential biopsies not only elevate therapeutic costs, but also can lead to emotional problems. Patient in mammography is exposed by ionization radiation that may have a negative effect on health such as leukemia. Another problem of mammography is low efficient recognition in young women. During the past two decades, the ultrasound technique has become an indispensable imaging modality for detection and diagnosis of breast lesions. The main superiority of ultrasound lies in its noninvasiveness and ability to efficiently capture the tissue properties [9,10]. It has been confirmed that the wrong negative recognition rate is decreased by using a different modality such as ultrasound [5]. Therefore, scientists are pursuing the application of ultrasonic imaging in breast cancer recognition [7]. In addition, ultrasound images can be used to increase the detection rate up to 17% [8]. Furthermore, the number of nonessential biopsies can decrease approximately by 40%. Therefore, annual medications cost is saved.

Ultrasound medical imaging uses low-power, high frequency sound waves to visualize the body's internal structures and create pictures of tissues.

The function of ultrasonic scanner is based on echo imaging [6]. By using a transducer, a high frequency and low power pulse of acoustic energy is emitted into the patient. This echo is acted with blood and organ of a patient, and one part of transmitting energy returns back to the transducer, which is used for displaying

* Corresponding author.
E-mail address: imanelyasi@gmail.com (I. Elyasi).

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purpose. Base on the time delay and reflected light intensity, an image is produced.

Therefore, one of the benefits of ultrasonic imaging is the application of a simple technology. As a consequence, ultrasound scanners are very cheaper and more portable compared to other imaging methods. Unfortunately, Ultrasonic images are sensitive to noise, particularly speckle noise, which is a random noise pattern produced by the high number of scattering waves with random phases in the resolution cell of the ultrasound ray. The scattering waves may interfere destructively in cell resolution, producing any noise, or may interfere constructively, producing intense noise. Speckle noise produces fine-false structures that decrease contrast of images and wraps the actual boundaries of the tissue. In addition, it causes problems in the next stages of an image processing system such as edge detection, automatic segmentation, feature extraction and classification. Therefore, developing methods to reduce the speckle noise is the key to make the ultrasound image a valuable source.

In the past, several algorithms have been proposed for speckle noise reduction.

A removing speckle noise method has been proposed in [11], based on a modified non local filter.

In [12], at first, a Rayleigh-trimmed filter is applied to ultrasound images. Afterward, an anisotropic diffusion filter is employed to improve the method's performance.

In [13], a new nonlocal mean filter for speckle reduction is proposed.

In [14], a method is utilized based on super resolution and nonlinear diffusion for speckle reduction in ultrasound images.

In [15], a method is presented based on Laplacian pyramid and nonlinear diffusion. To reduce the speckle noise and to preserve the features, a coupled modified diffusivity function and gradient threshold is utilized in Laplacian pyramid domain. An absolute deviation estimator is used to calculate the value of gradient threshold.

In the Homomorphic filtering [16], uses a logarithmic transformation of the input image until becomes the multiplicative noise in additive noise. Denoising is performed in fast Fourier transform domain, and after the inverse fast Fourier transform is computed.

After Mallat was first proposed the idea wavelet transform [33], the use of multiscale methods for noise removal has attracted the researcher. At first, a method for speckle reduction in ultrasound images using wavelet was proposed in [34]. These methods utilize logarithmic transformation of the speckled image before wavelet denoising.

In [17], an adaptive data-driven exponential operator is used that works on wavelet coefficients of the ultrasound image to eliminate speckle noise.

A method is presented based on discrete ripplet transform and nonlinear bilateral filter [18]. At first, ripplet transform is applied to log transformed ultrasound images. Then, to improve efficiency, bilateral filter is used to the approximation ripplet coefficients.

In [19], a method for speckle reduction in contourlet domain is proposed, which applies to log transformed ultrasound images. Then an adaptive data-driven threshold in bayesian framework is used that operates on contourlet domain.

In [20], a method for decrease speckle noise ultrasound medical images is proposed. First, perform first level discrete wavelet transform on the image. A set of detail sub-bands is revealed at different directions. Then apply gaussian filtering on the vertical and diagonal details of the image. Based on the amplitude of the speckle noise, the kernel size of gaussian filter is obtained.

In [32], a method based on multiscale nonlinear Homomorphic for medical ultrasound images was proposed. At first, multiscale wavelet transform is applied to log transformed ultrasound images. The sub-band decompositions have alpha-stable distribution, and then a Bayesian estimator is designed that use this distribution.

In [35], a method for speckle reduction in contourlet domain is proposed for ultrasound images of breast.

In the present article, a combination of wavelet analysis and filtering method is proposed for speckle reduction.

In the wavelet analysis, the threshold plays an important role in the Speckle reduction.

The choice of small threshold leads to stay noisy image, and the choice of large threshold results for removing of the high number of image coefficients. Our method has several advantages. First, the threshold amount is changed from one level decomposition to another and from one sub-band to other sub-band. Second, it is consistent with the human visual system.

Third, high level of despeckling is performed in flat regions of the image. Contrastively, low level of despeckling is accomplished in the edge regions of the image to preserve the edges.

Basically, the proposed method is concentrated on speckle reduction; however, it can help clinicians to interpret ultrasound images.

The article is organized as follows: In Section 2, describes the techniques of Speckle reduction. In Section 3, proposes a new algorithm for speckle reduction that is combination of filtering techniques and wavelet domain techniques. Our algorithm is called Homogeneity Modified Bayes Shrink (HMBS). Experimental results and discussion are represented in Section 4 and conclusions are given in Section 5.

2. Speckle reduction

Speckle reduction methods are categorized into three groups:

1. Filtering methods [21,28].
2. Wavelet methods [23,24,30].
3. Compounding methods [26,27].

2.1. Filtering methods

The filtering methods are categorized into linear filters and nonlinear filters. Adaptive Mean filter and mean filters can be mentioned for linear filters, and nonlinear diffusion filter can be mentioned for nonlinear filters. Mean filter accomplishes spatial filtering in a square slider window known as the kernel; so that each pixel is substituted by averaging from its kernel. It is simple and is easy to implement. It can locally decrease the variance. But mean filter leads to high smoothing and blurring the image. To mitigate the result of blurring, the adaptive mean filters have been used. The purpose of adaptive mean filter was equilibrium between direct averaging in the similar area and all pass filtering in the edge area. They locally regulate to the attributes of the image and arbitrarily eliminate speckle noise from distinct image area. The adaptive mean filter applies image statistics characteristics to discover and retain edges and characteristics efficiently. So, by substituting it with a local mean value, speckle noise can be eliminated. Therefore, Adaptive mean filters are superior compared to mean filters, and can eliminate speckle noise and retain the edges. Nonlinear diffusion filter [29] is a nonlinear filter, where the orientation and intensity of the diffusion are adjusted by an edge detection function. This method eliminates speckle noise and preserves the edge of the image at the same time. Generally, methods that working base on filtering to eliminate the speckle noise is simple and very fast, but filtering methods are susceptible to the size and shape selected kernel. A selection of small kernel leads to deficient noise removing, and selection of large kernel leads to removing of edges and important details, in addition blurring the image.