DESPECKLING OF MEDICAL ULTRASOUND IMAGES BASED ON WAVELET DECOMPOSITION

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Abstract

In the paper is presented a new wavelet-packet domain technique for despeckling of medical ultrasound (US) images for improved clinical diagnosis. For modelling an image with speckle noise is used the generalized Gaussian distribution and generalized gamma distribution. For noise reduction is used modified homomorphic filter based on wavelet packet decomposition of the transformed US image.

Some experimental results are presented, obtained by computer simulation in the MATLAB environment. Implementation results are given to demonstrate the visual quality by suppressing of the speckle noise and preserving the organ surfaces with application in clinical diagnosis.

1. INTRODUCTION

Due to its non-invasive nature and easily portable devices, ultrasound imaging is nowadays used for the diagnostic and clinical studies of many diseases. The quality of US images is very important by detection of some pathological modifications in a body structures and tissues.

Speckle is a type of noise which generally masks the fine details of the US image, thereby making the interpretation of an US image difficult for medical diagnosis. Speckle noise is presented as the random mottling of the image with dark and bright spots which hides certain details [1]. As a result, despeckling methods are necessary to enhance the image quality and increase the diagnostic value of medical US images. In [2] is demonstrated that the speckle is signal-dependent in the sense that the mean is proportional to the standard deviation of the speckled image. The multiplicative nature of the speckle was proposed in [3] where the multiplicative noise is converted to an additive one through log transformation and the problem of despeckling is thus reduced to the estimation of signal in the presence of additive noise. Wiener filtering can be used in order to reject the additive noise, followed by an exponential transformation. This algorithm is general because it allows further modification by replacing the linear Wiener filter with other filtering schemes. The application of the wavelet transform for despeckling of medical US images was reported in [4]. These methods use logarithmic transformation of the speckled image before wavelet denoising. After the log transform, the speckle can be approximated by zero-mean additive white Gaussian noise, and estimators/filters are designed accordingly. The methods are referred to as the homomorphic wavelet based despeckling (HWDS) methods. The most studies show that despeckling of an US image is major research problem and the performance of HWDS schemes may be improved by an accurate analysis of the statistical properties of the log-transformed speckle noise. In [5] is proposed to model the speckle in the detailed wavelet sub-bands of log-transformed US images by the generalized gamma distribution (GGAD) and use the model for despeckling in the Bayesian framework and the noise is removed in Discret Wavelet Transform (DWT) domain.

This paper proposes to use a similar model an image with speckle noise based on the generalized Gaussian distribution and generalized gamma distribution. We use for noise reduction a modified homomorphic filter based on wavelet packet decomposition and adaptive threshold of the transformed US image.

The paper is arranged as follows: In Section 2 is described the speckled image model; In Section 3 is presented the main algorithm of processing; in Section 3 are given some experimental results, obtained by computer simulation and their interpretation; in Section 4 - the Conclusion.

2. SPECKLED IMAGE MODEL

It is defined that the fully-developed speckle is a multiplicative noise and can be modeled as:

$$I(x,y) = g(x,y).n(x,y) \quad (1)$$

where, *I* and *g* are the observed noisy image and noise-free image, respectively, *n* is the noise variable modeled as a stationary unity means random variable independent of *g*. The homomorphic despeckling methods take the advantage of the logarithmic transformation that, when applied to both sides of Eq.(1), converts the multiplicative noise into an additive one:

$$\ln I(x,y) = \ln g(x,y) + \ln n(x,y) \quad (2)$$

The wavelet transform now becomes a linear operation. In this case the application of the WPT to the noisy image *ln I(x,y)* gives:

$$W[\ln I(x,y)] = W[\ln g(x,y)] + W[\ln n(x,y)] \quad (3)$$

where *W* is the WPT operator. So the Eq. (3) can be rewritten as:

$$Y = X + N \quad (4)$$

where, *Y*, *X*, and *N* are the random variables representing wavelet coefficients, respectively, of the noisy data, noise-free data, and the noise in Equation (2).

For most of images, the signal components in the detail sub-bands after wavelet decompositions have heavier tails and are sharply peaked at zero. They are described by the zero- mean generalized Gaussian distribution (GGD). Some limiting case of the GGD is the gamma distribution. We have used the generalized gamma model, which is more general than the Gaussian to approximate the speckle statistics in the sub-band representation of US images [5].

3. GENERAL ALGORITHM FOR SPECKLE NOISE REDUCTION OF US IMAGES

In this paragraph is presented the general algorithm, used to reduce speckle noise. Fig. 2 presents the block diagram of the proposed algorithm. For filtering stage is used a wavelet packet decomposition issued from a given orthogonal wavelets. As this number may be very large, it is interesting to find an optimal decomposition with respect to a conventional criterion. The classical entropy-based criterion is a common concept [6]. In obtained best shrinkage decomposition is used soft threshold on all highpass sub- bands to reduce the wavelet coefficients, regarding to chosen model of the speckle statistics in the sub-band representation of US images.

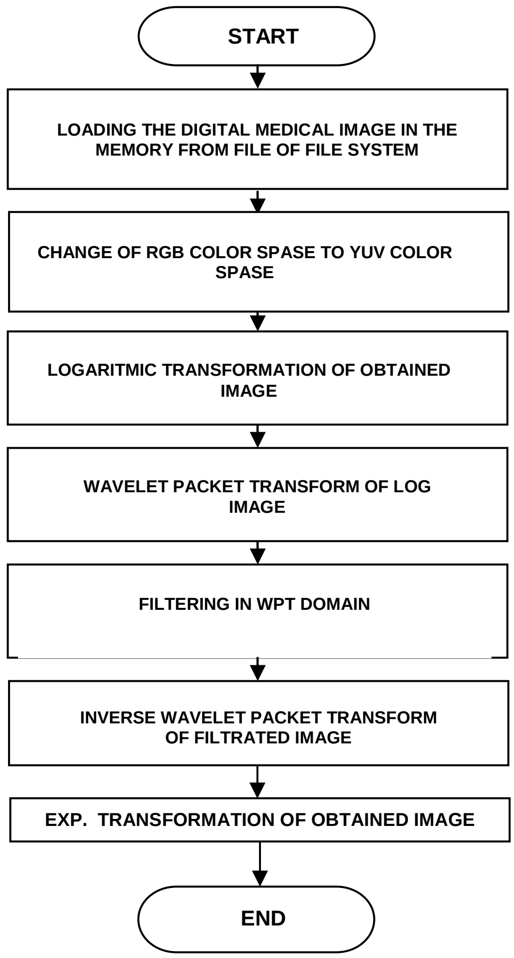

Figure 2. Block diagram of the General Algorithm for Despeckling of US Images

4. EXPERIMENTAL RESULTS

The formulated stages of processing are realized by computer simulation in MATLAB 7.14 environment by using IMAGE PROCESSING and WAVELET TOOLBOXES [7]. In analysis are used 20 US images from kidney with size 640x480 pixels in jpg file format. For processing they are converted in bmp. format.

Some results from simulation, which illustrate the working of proposed algorithm, are presented in the next figures below.

In Fig. 2 is shown the original US abdominal image of right kidney.

The best shrinkage decomposition is obtained by Shannon entropy criterion on level 2. In Fig. 3 is presented this decomposition and the original image in node (0,0).

Fig. 4 presents the wavelet packet decomposition and the processed image after filtration in node (5,0).

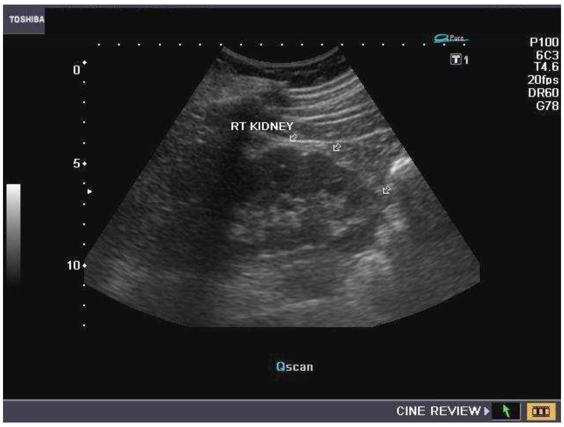

Figure 2. Original US image of right kidney

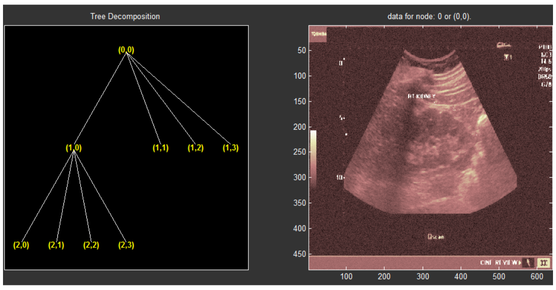

Figure 3. Wavelet decomposition and the original US image

The presented figure illustrates the visual enhancement of the processed images.

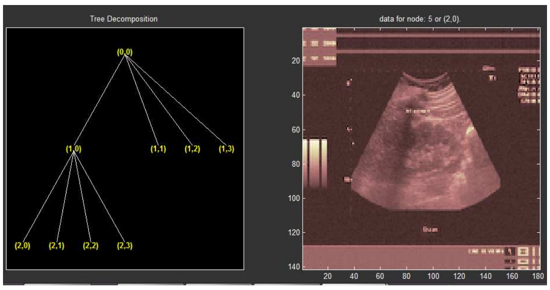

Figure 4. Wavelet decomposition and the processed US image

In Fig. 5 is shown the US image after speckle noise reduction.

Figure 5. US image of right kidney after speckle noise reduction

In the paper are analyzed some quantitative estimation parameters: Noise reduction ratio (NNR), Signal to noise ratio in the noised image (SNR_Y), Signal to noise ratio in the filtered image (SNR_F), Effectiveness of filtration (E_{FF}), Peak signal to noise ratio (*PSNR*). The obtained averaging results by calculation of some estimations parameters are presented in Table 1. They are compared with the parameters, obtained with the algorithm on the base of DWT.

Table 1. Simulations results

Method of processing	Estimations Parameters			
	PSNR [dB]	**SNR_Y [dB]**	**SNR_F [dB]**	**E_{FF} [dB]**
HM based on DWT	24.619	9.304	10.362	1.058
HM based on DWPT	27.327	9.304	11.224	1.920

The obtained result for noise reduction ratio (NRR) by the method of homomorphic filtering based on DWT is 0.502 and shows that the noise is reduced about two times. This parameter is better by our method of homomorphic filtering based on WPT and adaptive threshold. It is 0.221 and shows, that the noise is reduced about 5 times.

The presented results show that the proposed approach is more effective by speckle noise reduction in comparison with DWT.

5. CONCLUSION

In the paper is presented a new and effective approach for speckle noise reduction in US images. The implemented study and obtained results show its advantage by applying of WPT in homomorphic filtering schema as DWT.

The proposed method can be used in a preprocessing stage for future segmentation of kidney or other organs, as well for future analysis and classification of diseases.

Our future work will be concentrated in effective enhancement techniques and methods for segmentation of kidney or other organs.

5. ACKNOWLEDGMENTS

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