An Approach for Medical Ultrasound Images Enhancement

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Abstract

In the paper is presented a complex post processing of ultrasound images (US) images that combines different methods for image enhancement. This includes increasing of brightness and contrast of all image, following by noise reduction on the base of 2D wavelet packet transformation. As next stage is proposed to select region of interest (ROI) and morphological filtering of the selected ROI. That allows detail preservation and contours determination of the investigated object. By properly choosing of top & bottom hat filtration and suitable form of structuring element, local structures can be eliminated or local geometry of the investigated object can be modified.

An effective algorithm was treatment by optimization of some parameters of the wavelet transformations and studying for the most suitable morphological operator and structuring element on the base of objective quantitative estimation parameters. The main goal is noise reduction and improving the quality of the diagnostic ultrasound images.

Some results of the experiments are presented, which were made by computer simulation in MATLAB environment.

Keywords: US images enhancement, morphological processing, noise reduction, wavelet packet transformations

1. INTRODUCTION

The quality of US images is very important by detection of some pathological modifications in a body structures and tissues. In many practical cases available medical apparatus cannot provide for such high quality of the images. It's necessary to make some post processing for US image enhancement. This is indispensible by reason of specific noise in US images, arising by their formation. The values of the noised components in the image can be greater.

The conventional methods of filtration basic on the processing in spatial domain, can not give a high quality for the ultrasound images, which needed for precise diagnostic. In [1] is presented an approach for US Images enhancement included histogram equalization and wavelet (DWT) denoising. It is applied to images, obtained by high frequency of US signals (gastroenterology). In this case the existing noise components are smaller and the quality of the image is better.

In the paper is presented another approach (applied in cardiology), included histogram equalization, following by "gamma correction" and noise reduction on the base of wavelet packet transformation (WPT).These methods can propose more complete analysis that provides increased flexibility. They have the following important properties:

- A richer presentation of the image, basic on functions with wavelet forms, which consist of 3 parameters: position, scale and frequency of the fluctuations around a given position;
- Numerous decompositions of the image, that allows estimate the noise reduction of different levels of its decomposition;
- Adaptive noise reduction on each level of the decomposition by choice of best tree decomposition and optimal thresholds parameters.

The next stage in algorithm is selection of ROI and its morphological processing. The morphological filters are used to image enhancement and detection of geometric structure of image objects. They are more suitable than linear filters for shape analysis and offer efficient solutions to other nonlinear tasks such as non-Gaussian nose suppression.

Some quantitative estimation parameters: Coefficient of noise reduction (CNR), 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) have been analyzed in the paper [2].

2. BASIC STAGES OF THE ALGORITHM

2.1. Brightness and contrast enhancement

It has been proposed to modify US image's histogram for enhancement of the brightness of this image. In many cases of US image processing are made color

histogram equalization [3]. That is made separately for R, G and B components of the image.

This approach proposed processing of the image in YUV system and equalizing the global histogram of its Y component [4]. So, this is a method to be obtained an even distribution of the brightness for all levels in the processed image. The brightness can be increased in the dark regions, also. In many real cases the transmission characteristic of the brightness is nonlinear. Because of that in the paper has been proposed to make "gamma correction" to the modified Y component of the US image [4]. As result the contrast of the small details in the investigated object can be increased in comparison with the simple linear contrasting.

2.2. Noise reduction on the base of 2D wavelet packet transformation

The values of the noised components in the image can be greater. The noise components in real US images have different character [5]. For their analysis can be used not only multiplicative model for speckle noise, but also additive mathematical model for other noise components. An additive model has been proposed in the paper. It presented the influence of the complex noise components.

The wavelet packet analysis is a generalization of wavelet decomposition that offers a richer image analysis. Based on the organization of the wavelet packet library, it can be determinate the decomposition issued from a given orthogonal wavelets. A signal of length $N = 2^L$ can be expand in α different ways, where α is a number of binary sub trees of a complete binary tree of a depth L. The result is $\alpha \geq 2^{N/2}$ [6]. As this number can 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. It's looking for minimum of the criterion from three different entropy criteria: the energy of the transformed in wavelet domain image, entropy by Shannon and the logarithm of the entropy by Shannon [7].

Looking for best shrinkage decomposition to noise reduction, two important conditions must be realized together [8]. The conditions (1) and (2) are following:

$$E_K(S) = \min, \quad for\, K = 1,2,3...n \quad , \tag{1}$$

where E_K is the entropy in the level K for the best tree decomposition of image S

$$s_{ij} \geq T \, , \tag{2}$$

where s_{ij} are the wavelet coefficients of S in an orthonormal basis, T is the threshold of the coefficients.

By determination of the threshold it is used the strategy of Birge-Massart [9]. This strategy is flexibility. It used spatial adapted threshold that allows to determinate the threshold in three directions: horizontal, vertical and diagonally. In addition the threshold can be hard or soft.

2.3. ROI selection

The next stage in the processing is to define a ROI from the filtered image. The investigated object can be selected by interactive procedure with the mouse from the operator (physician). The result of automatically detached rectangular ROI image is written in file format. It can be used in next processing.

2.4. Morphological processing of the selected ROI

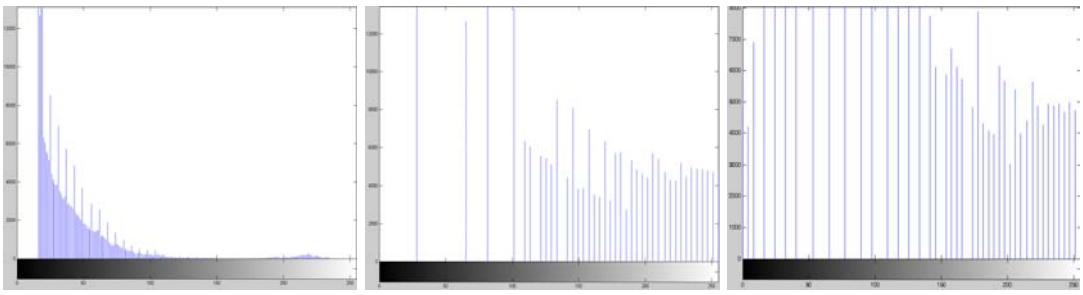
A morphological processing of the high frequency subbands of the wavelet decomposition has been proposed for detail preservation abilities is proposed. This stage includes morphological filtering by mean of top & bottom hat operation [10]. It increased the contrast of the object by means of increasing the details in the dark regions and near by contours. The top & bottom hat filtering extracts the original image from the morphologically closed version of the image. An investigation has been done for the influence of three different flat structuring elements (SE): line, disk-shaped and diamond-shaped with different sizes. The well-suited structuring element and its size for US images can be selected on the base of some objective quantitative estimation: by minimum value for CNR and maximum values for PSNR and E_{FF}.

3. EXPERIMENTAL RESULTS

The formulated stages of processing are presented by computer simulation in MATLAB, version 7.2 environment with using the IMAGE PROCESSING and WAVELET TOOLBOXES. In analysis are used 20 ultrasound images from cardiology with different sizes. The original images have been done in different file formats: tiff, jpeg, bmp, but all of them are converted in bmp. All images are 24 bpp, in RGB system. By post processing they are converted in YUV system.

Figure 1 presents histograms of Y component for US image of size 640x480 pixels. It illustrates the computed, equalized and the histogram after noise reduction on the base of wavelet packet transformation. The experimental results showed enhancement of

the image and increasing of image information in consequence of brightness level restoration.



a) b) c)

Figure 1. Histograms of Y component of US image:

a) computed; b) equalized; c) computed after noise reduction

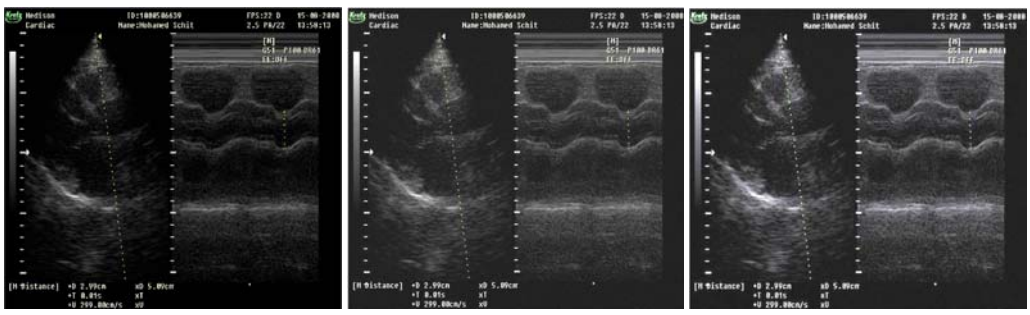
The obtained average results from the simulation are presented in Table 1.

Table 1. Simulation results

Basic stages of processing	**PSNR [dB]**	**CNR**	SNR_Y **[dB]**	SNR_F **[dB]**	E_{FF} **[dB]**
Histogram equalization	20,8105	-	-	-	-
Noise reduction	29,7841	0,2112	17,0731	19,5411	2,4680
Morph. processing	31,2972	0,3617	19,5411	20,7315	1,1904

The best results for all images are obtained with the line structuring element (length=3; angle=0 degree) by top& bottom hat operator. The values of PSNR and Effectiveness of filtration (E_{FF}) are maximum and the value of CNR is minimum (0.3), and shows that the noise is about three times reduced.

On Figure 2 are presented: the original US image, the processed image for brightness and contrast increasing and filtered image on the base of wavelet transformation.



a) b) c)

Figure2. Original and processed US images:

a) the original image; b) image with increased brightness and contrast; c) filtered image.

In Figure 3 can be shown the graphical responses of CNR and E_{FF} by image post processing in RGB and YUV systems. That presented the preference of the proposed approach for US image post processing. Figure 4 illustrates the selected ROI of size 270x160 pixels from the filtered image and its morphological modification with top & bottom hat operator by using a line structuring element (length=3; angle=0 degree) and disk-shaped structuring element with radius R=4 . By using of disk-shaped structuring element and especially a diamond-shaped structuring element can be obtained well-defined outlines of some tissues, but the values of the noised components in the image can be greater.

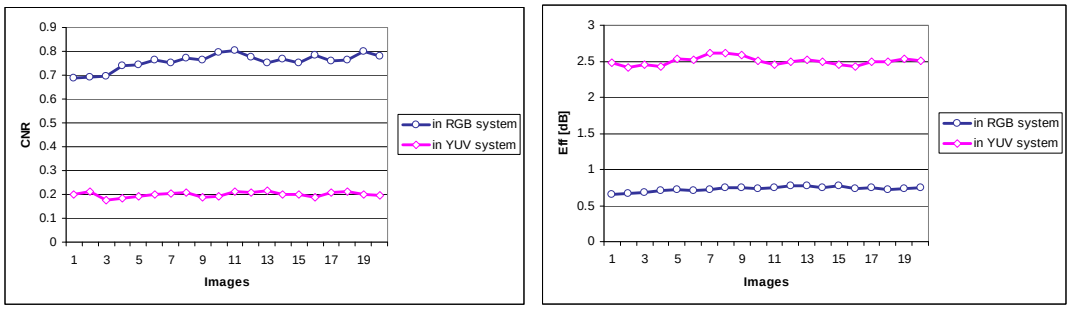
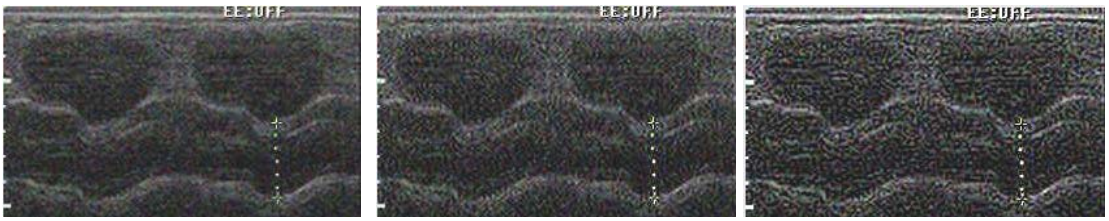


Figure 3. Graphical responses of CNR and E_{FF}



a) b) c)

Figure 4. Selected ROI: a) before morph. processing; b) morph. processing with line SE; c) morph. processing with disk SE;

4. CONCLUSION

A new and effective approach for US image enhancement has been proposed in the paper. The complex processing has an effect of brightness and contrast enhancement, noise reduction and contours determination of objects for selected ROI of different parts of medical diagnostic US images. The implemented investigation and obtained results by using real images attempt to make diagnostic more obvious.

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