EDGE DETECTION IN ULTRASOUND MEDICAL IMAGES USING WAVELET DECOMPOSITION

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Abstract

In the paper is presented a new approach to edge detection using wavelet packet decomposition. The proposed wavelet based edge detection algorithm combines noise reduction with edge detection on a series of scales to achieve better results for shape and contours of different objects in the ultrasound (US) image. To reduce the specific noise, the input US image is decomposed on the base of wavelet packet transformation (WPT) by using soft threshold on all highpass subbands. The wavelet transform characterizes the local regularity of signals by their decomposing into elementary building blocks that are well localized both in space and frequency. This not only explains the underlying mechanism of classical edge detectors, but also indicates a way of constructing optimal edge detectors under specific working conditions. Then the wavelet model is applied for Canny edge detector to develop a multiscale wavelet model for edge detection.

In the paper are presented some results obtained by using the proposed algorithm. They are compared with results obtained by using of classical Canny edge detector and multiscale edge detector based on discrete wavelet transformation (DWT).

1. INTRODUCTION

Edge detection is a fundamental issue in image analysis. The classical edge detectors work fine with high-quality images, but often are not good enough for noisy medical images (especially in case of ultrasound images) because they cannot distinguish edges of different significance. There are two kinds of noise typically for US images: speckle noise and white noise [1]. Due to the presence of speckle, which can be modeled as a strong multiplicative noise and white noise can be modeled as an additive noise, edge detection in US images is difficult and methods developed for optical images are generally applied after a process of noise reduction. On the other hand approaches based on wavelet transform has been proposed separately for noise reduction and edge detection. Many existing methods for multiscale edge detection are based on DWT [2], [3].

In the paper is proposed to incorporate noise reduction and multiscale edge detection in US medical images as a single process. To reduce the specific noise, the input US image is decomposed on the base of WPT by using soft threshold on all highpass subbands. Then the wavelet model is applied for Canny edge detector to develop a multiscale wavelet model for edge detection.

2. STAGES FOR US IMAGES EDGE DETECTION

In this paragraph are presented the basic stages of the algorithm, used to improve image edge detection, shown in Figure1.

2.1. Noise model and preprocessing stage

In an image contained additive Gaussian white noise the basic model for each pixel is as follows (1):

$$s(x,y) = f(x,y) + n(x,y) \qquad (1)$$

where $f(x,y)$ is the desired image, without noise, $n(x,y)$ is N(0,1) noise.

As speckle noise is proportional to the desired signal it is generally modeled as multiplicative noise (2):

$$s(x,y) = f(x,y).n(x,y) \qquad (2)$$

where $f(x,y)$ is the desired image, without noise, $n(x,y)$ is the noise.

Logarithmic transformation of a US image converts the multiplicative noise model to an additive noise model (3):

$$\log(s) = \log(f) + \log(n) \qquad (3)$$

Our goal is to extract f and reduce the noise n.

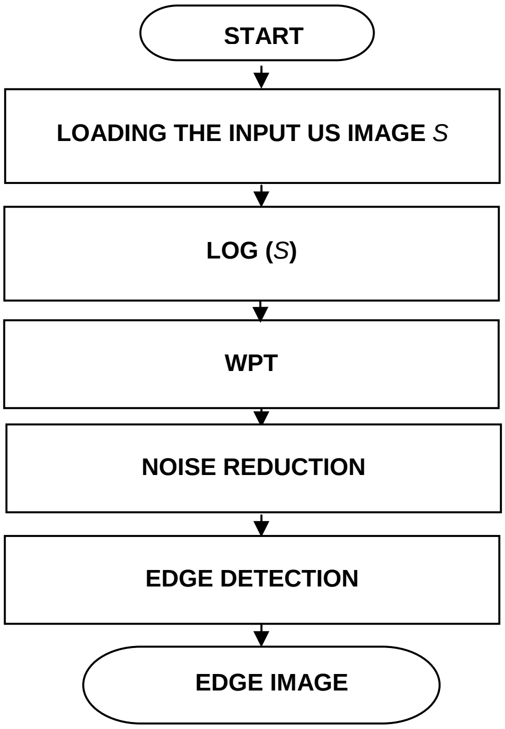

Fig. 1. Block diagram of the algorithm

2.2. Noise reduction

The next stage of the algorithm is noise reduction. It is based on the wavelet packet transform [4]. The wavelet packet analysis is a generalization of wavelet decomposition that offers a richer image analysis [5]. Based on the organization of the wavelet packet library, it can be determinate the 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. 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 [6]. By looking for best shrinkage decomposition to noise reduction two important conditions must be realized together [7]. They are the conditions (4) and (5):

$$E_K(S) = \min, \quad for\, K = 1,2,3...n \qquad (4)$$

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

$$s_{ij} \geq T \qquad (5)$$

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. This strategy is flexibility and used spatial adapted threshold that allows to determinate the threshold in three directions: horizontal, vertical and diagonally. It is focused on soft thresholding technique which consists in putting to zero all detail wavelet coefficients of amplitude smaller than T, reducing the amplitude of the other coefficients by the quantity T [5].

2.3. Edge detection

Wavelet filters of large scale are more effective for noise reduction, but at the same time increase the uncertainty of the location of edges. Canny edge detection method is optimal for step edges corrupted by white noise, with application of additive noise model. It is used three criteria to design edge detector. The first requirement is reliable detection of edges with low probability of missing true edges, and a low probability of detecting false edges. Second, the detected edges should be close to the true location of the edge. Third, there should be only one response to a single edge. Canny edge detection uses the first derivative of a Gaussian as its filter. The choice of the standard deviation σ for the Gaussian filter depends on the size, or scale, of the objects contained in the image. From the point of wavelet transforms, it can be used more effective approach to adjust the scale of the filters. So the wavelet best shrinkage decomposition to noise reduction of the US image can be used as wavelet model for Canny edge detection. The level of decomposition can be selected in depending on the requirement of details desired in the edges.

3. EXPERIMENTAL RESULTS

The formulated stages of processing are realized by computer simulation in MATLAB environment by using IMAGE PROCESSING TOOLBOX and WAVELET TOOLBOX. In analysis are used 20 grayscale US images from cardiology with size 640X 480 pixels.

Errors as "missed detection" and "false alarm" in edge detection are minimized when the SNR of the detection filter is maximized. In the paper are analyzed 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}), PSNR [8]. In Table 1 are presented the obtained average results from simulation by using the proposed algorithm. They are compared with results obtained by using of classical Canny edge detector and multiscale edge detector based on discrete wavelet transformation (DWT).

Table1. Simulations results

Method of edge detection	Estimations Parameters				
	PSNR [dB]	CNR	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Canny edge detection (CED)	21.963	0.857	4.515	7.463	3.947
Noise reduction with DWT+CED	23.812	0.533	6.949	12.116	5.167
Noise reduction with WPT+CED	23.855	0.255	11.518	16.739	5.862

The best results are obtained by proposed approach including noise reduction on the base of WP transformation. The CNR is minimum (0.25) and shows that the noise is four times reduced. The values of SNR_F, E_{FF} and PSNR are more sufficient.

On Figure 2 is illustrated the original grayscale US image of size 640x480 pixels. On Figure 3 is shown its edge map image, obtained from Canny edge detection method. On Figure 4 is illustrated the edge map image after noise reduction on the base of DWT and Canny edge detection.

Figure 5 presents the edge map image for the proposed approach. The best shrinkage decomposition to noise reduction is obtained by Shannon entropy criterion. In depending on the requirement of details desired in the edges the selected level of decomposition is 3.

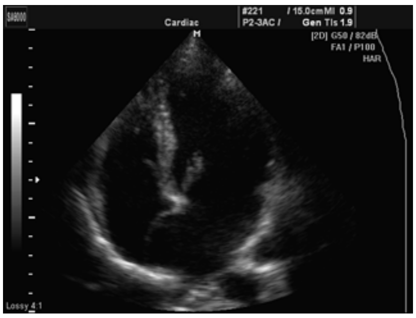

Fig. 2. Original US image

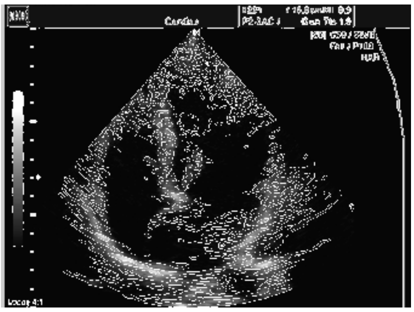

Fig. 3. Edge map of US image, obtained by Canny edge operator

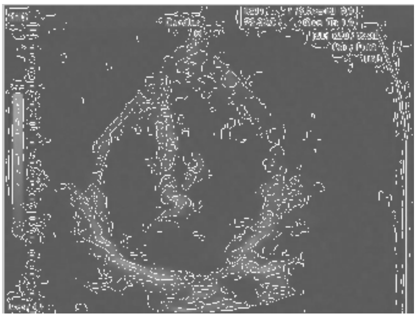

Fig. 4. Edge map of US image, obtained by noise reduction on the base of DWT and Canny edge operator

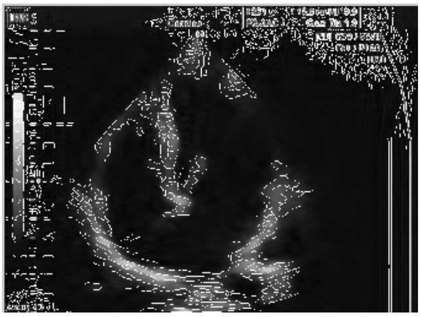

Fig. 5. Edge map of US image, obtained by proposed approach

4. CONCLUSION

In the paper is presented a new approach to edge detection using wavelet packet decomposition. The proposed wavelet based edge detection algorithm combines noise reduction with edge detection on a series of scales to achieve better results for shape and contours of different objects in the ultrasound images. The implemented studying and obtained results by using of real images attempt to make diagnostic more precise.

The proposed approach can be demonstrated by studying of medical image processing in engineering and medical education.

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