EDGE DETECTION IN SEQUENCES OF CT IMAGES

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Abstract

In the paper is presented an approach for edge detection, which combines noise reduction with edge detection on a series of scales to achieve better results for shape and contours of different objects in sequences of CT images. So can be easier marked the differences in the inter sequence images in regard to observe better the changes in medical structures. To reduce the specific noise, the input CT image is decomposed on the base of wavelet packet transformation (WPT) by using of adaptive threshold of wavelet coefficients in the high frequency sub-bands of the shrinkage decomposition. Then the wavelet model is applied for Canny edge detector to develop a multiscale wavelet model for edge detection.

Implementations results are given to demonstrate the visual difference in 2 inter sequence images and some objective estimation parameters in the perspective of clinical diagnosis.

1. Introduction

Noise in CT is a multi-source problem and arises from the fundamentally statistical nature of photon production. This noise is not independent of the signal. It's Poisson distributed and independent of the measurement noise [1]. The measurement noise is additive Gaussian noise and usually negligible relative to the quantum noise. It comes from the motion of patient. The classical edge detectors work fine with high-quality images, but often are not good enough for noisy medical images. 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 CT images as a single process. To reduce the specific noise, the input CT images are decomposed on the base of WPT by using adaptive soft threshold on all high-pass subbands of the shrinkage decomposition [4]. Then the wavelet model is applied for Canny edge detector to develop a multiscale wavelet model for edge detection [5]. On the base of the obtained edge maps of two consecutive CT images can be observe the specific difference in the shape and contours of medical objects.

2. Stages for CT images edge detection

In this paragraph are presented the basic stages of the algorithm, used to improve image edge detection and to demonstrate the difference by two consecutive CT images in the sequence, shown in Figure 1.

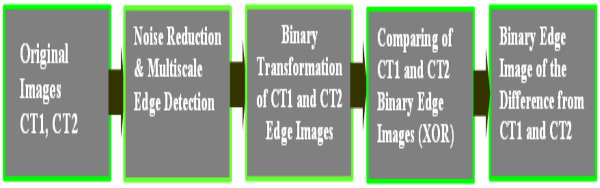


Figure 1. Block diagram of the algorithm

2.1. Noise reduction and multiscale edge detection

The first stage of the algorithm is noise reduction. It is based on the wavelet packet transform [4].

In an image contained Poisson noise can be presented as an additive noise 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 the noise.

The block diagram of this stage is presented in Figure 2.

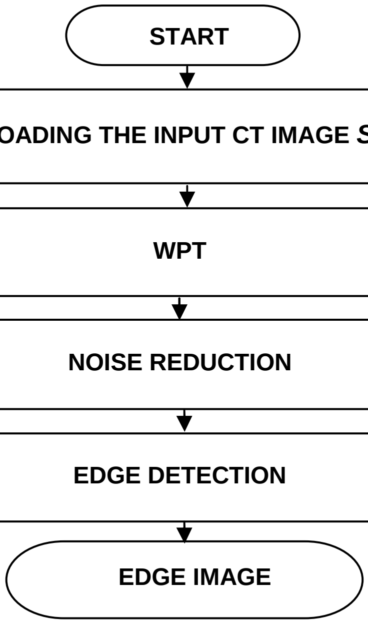


Figure 2. Block diagram of the stage for noise reduction and edge detection

The wavelet packet methods for noise reduction give a richer presentation of the image, based on functions with wavelet forms, which consist of 3 parameters: position, scale and frequency of the fluctuations around a given position. They propose numerous decompositions of the image, that allows estimate the noise reduction of different levels of its decomposition. For the given orthogonal wavelet functions exists library of bases, called wavelet packet bases. Each of these bases offers a particular way of coding images, preserving global energy, and reconstructing exact features. Based on the organization of the wavelet packet library, it is determinated the decomposition issued from a given orthogonal wavelets. An optimal decomposition is used with respect to a conventional criterion. The criterion is a minimum of three different entropy criteria: the energy of the transformed in wavelet domain image, Shannon entropy and the logarithm of energy [6]. By determination of the global threshold it is used the strategy of Birge-Massart [7]. It uses spatial-adapted threshold, which allows to determinate the thresholds in three directions: horizontal, vertical and diagonally. Choosing the threshold too high may lead to visible loss of image structures, but if the threshold is too low the effect of noise reduction may be insufficient. The procedure for noise reduction can be determined on the base of the calculated estimation parameters. PSNR and E_{FF} values are higher for better denoised CT image where the value of NRR is lower.

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 with application of additive noise model. 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 CT 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.

2.2. Binary transformation of CT edge images and comparing of their differences

To better compare the images we use the standard Otsu method [8] to transform the grayscale to a binary image and then find the difference between two consecutive images. The Otsu method for image binarization chooses an adaptive threshold to minimize the intraclass variance of the black and white pixels of the transformed image. Then in the output image we replace all pixels in the input image with luminance greater than **the threshold** with the value 1 (white) and replace all other pixels with the value 0 (black). Finally to compare the two images we perform an exclusive OR operation on the corresponding pixels of the two images. The resulting binary image's pixel is logical true (**1**) if **the first** image pixel or the second image pixel, but not both, are nonzero.

3. Experimental results

The formulated stages of processing are realized by computer simulation in MATLAB environment by using IMAGE PROCESSING TOOLBOX and WAVELET TOOLBOX. The image data consists of grayscale CT-slices images of the liver of size 512x512 pixels, 16 bits in DICOM format archived in 12 series. The simulation is made with additive Poisson noise with intensities values between 0 and 1 and corresponding to the number of photons divided by 10^{12}. The best results for the investigated sequence of CT images are obtained by the third, fourth and fifth level of the shrinkage decompositions. For noise reduction is used soft threshold. 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: 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 and SSIM. 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). The best results are obtained by proposed approach including noise reduction on the base of WP transformation.

This comparison is very difficult through large variations of liver geometry between patients, the limited contrast between the liver and the surrounding organs and different amplitude of noise.

Table 1. Simulations results

Method of edge detection	Estimations Parameters				
	PSNR [dB]	SSIM	SNR_Y [dB]	SNR_F [dB]	E_{FF} [dB]
Canny edge detection (CED)	24.865	0.6	14.515	15.463	1.947
Noise reduction with DWT+CED	27.814	0.7	15.949	17.986	2.037
Noise reduction with WPT+CED	29.988	0.8	16.313	19.832	3.519

A visual presentation of the obtained results for the processed 2 consecutive images in sequence of 6 CT images can be seen in the next figures below.

In Figure 3 and Figure 4 are shown respectively the original and denoised CT1 and CT2 images. Figure 5 presents edge maps of the denoised CT1 and CT2 images. In Figure 6 are given respectively the obtained differences of original and denoised binary edge images.

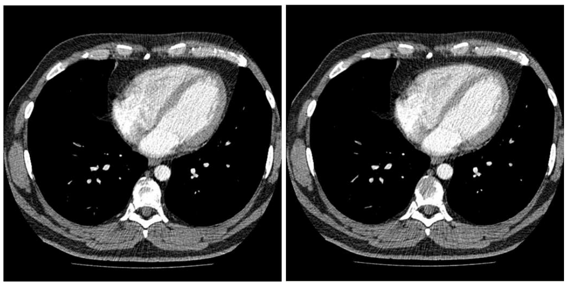


Figure 3. Original CT1 and CT2 images

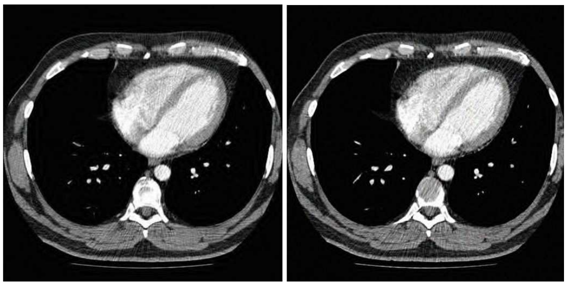


Figure 4. Denoised CT1 and CT2 images

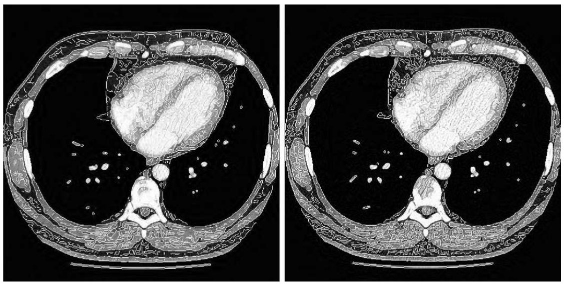
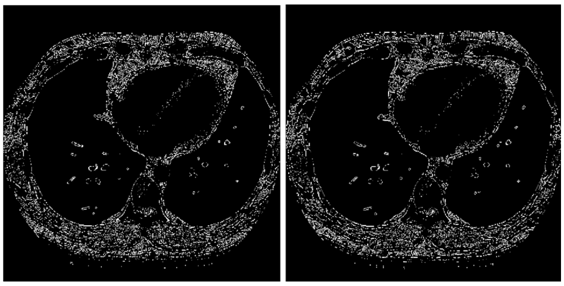


Figure 5. Edge maps of denoised CT1 and CT2 images



a) *b)*

Figure 6. Binary edge images of the differences: a) of original CT1 and CT2; b) of denoised CT1 and CT2 images

4. Conclusion

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 sequences of CT images. The differences in the inter sequence images can be easier marked in regard to observe better the changes in medical structures. So the noise reduction process can't be applied by differences in the inter sequence images in the case of reiteration of elements in the same position for loss of specific medical information. The proposed approach can be used in clinical diagnosis or by modeling of anatomical organs and theirs visualization in 3D.

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