NOISE REDUCTION AND ENHANCEMENT OF COMPUTED TOMOGRAPHY IMAGES

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Abstract

Computed tomography (CT) presents images of cross-sectional slices of the body. The quality of CT images varies depending on penetrating X-rays in a different anatomically structures. This noise is not independent of the signal. It's Poisson distributed and independent of the measurement noise.

In the paper is proposed a new and effective approach for CT image enhancement. The complex processing has an effect of contrast enhancement, noise reduction and contours determination for selected ROI of different parts of diagnostic CT images. The implemented studying and obtained results by using of real images attempt to make diagnostic more precise.

1. INTRODUCTION

CT images have a lower resolution as X-ray images, typically 512x512 pixels in digital format. The quality of CT images varies depending on penetrating X-rays in a different anatomically structures. The noise problem arises from the fundamentally statistical nature of photon production. The quantum noise is dominant and comes from the quantization of energy into photons. This noise is not independent of the signal. It's Poisson distributed and independent of the measurement noise [1]. We cannot assume that, in a given pixel for 2 consecutive but independent observation intervals of length T, the same number of photons will be counted. The measurement noise is additive Gaussian noise and usually negligible relative to the quantum noise. It comes from the motion of patient [1].

Image enhancement is one of the categories of image processing, attempt to make diagnostic more obvious. In this work is presented an approach for selecting regions of interest, increasing the image contrast for selected ROI and noise suppression and detail preservation abilities of the selected ROI, based on morphological processing and wavelet transformations. By properly choosing of opening, closing filtration and 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 [2]. The reduction of noise components is made on the base of 2D wavelet packet transformations. To improve the diagnostic quality of the selected object are optimized some parameters of the wavelet transforms such as: determination of the wavelet packet function, determination of best shrinkage decomposition, threshold of the wavelet coefficients and value of the penalized parameter of the threshold. 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}), Peak signal to noise ratio (PSNR) [3].

2. STAGES FOR CT IMAGES PROCESSING

Image enhancement techniques are applied to real digital grayscale CT images of the head and abdominal tissues that exhibited diverse pathology.

In this paragraph are presented the three basic stages of the algorithm, used to improve image quality.

The first stage in CT image processing is to define a ROI from the image. It can be selected in interactive procedure from the operator. The result of ROI image is written in a file format that can be used in next processing.

The second stage is increasing the contrast. For that step is necessary first to increase the gray level contrast between the pixels, using gamma correction. This procedure can be applied to Y component of the selected image that is processing in YUV system. The next step in the processing included morphological operators: opening, closing and top & bottom hat filtering, which are used to enhance contrast in the image. The morphological operators are compared together and one of them is estimated as a most effective method. The top & bottom hat method is a well-suited. 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. For this operation is used a disk-shaped structuring element.

The third stage of the algorithm is noise reduction. It is based on the wavelet packet methods. 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 $\alpha \geq 2^{N/2}$ [4]. 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 [5]. By looking for best shrinkage decomposition to noise reduction two important conditions must be realized together [6]. The conditions (1) and (2) are following:

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

where E_K is the entropy in the level K for the best tree decomposition of the 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 [7]. This strategy is flexibility and 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. The noise reduction is applied on Gaussian and Poison distributed noise components.

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 CT images of the head and abdominal tissues that exhibited diverse pathology.

The obtained average results from simulation are presented in Table1.

The best results are obtained by noise reduction of Poisson noise on the base of WP transformation. The CNR is minimum (0.3) and shows that the noise is three times reduced. The values of PSNR and Effectiveness of filtration (E_{FF}) are more sufficient.

Table 1. Simulations results

CT image Processing	PSNR [dB]	SNR_y [dB]	SNR_F [dB]	E_{FF} [dB]	CNR
Contrast increasing and morph. filtering	20.7803	17.4120	18.0297	0.6177	0.8423
Gaussian noise reduction with WPT	30.4624	18.0297	19.6728	1.6431	0.5321
Poisson noise reduction with WPT	32.2139	18.0297	20.2342	2.3442	0.3435

The graphical presentations of the obtained results for PSNR are shown on Figure 1.

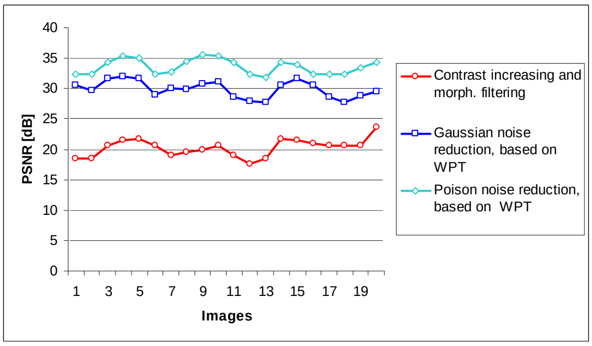

Fig. 1. The graphical presentation of PSNR for investigated CT images

The graphical presentations of the obtained results for E_{FF} are shown on Figure 2.

The graphical presentations of the obtained results for CNR are shown on Figure 3.

On Figure 4 is illustrated the original CT image of size 832x659 pixels.

Figure 5 presents selected ROI from the original CT image of size 196x152 pixels. In Figure 6 is shown the selected ROI with contrast increasing. In Figure 7 is presented the result from the following wavelet filtration of Gaussian noise. Figure 8 illustrates the following wavelet filtration of Poison noise.

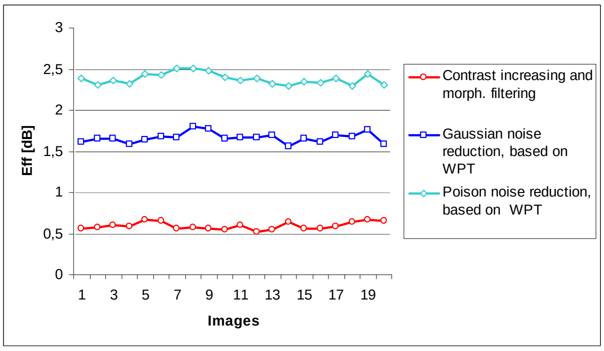

Fig. 2. The graphical presentation of E_{FF} for investigated CT images

Fig. 3. The graphical presentation of CNR for investigated CT images

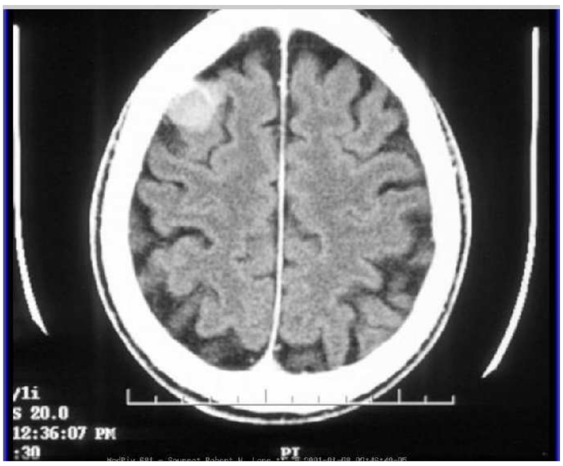

Fig. 4. The original CT image

The obtained result shows that this approach is more effectiveness by image enhancement and noise reduction of Poison noise.

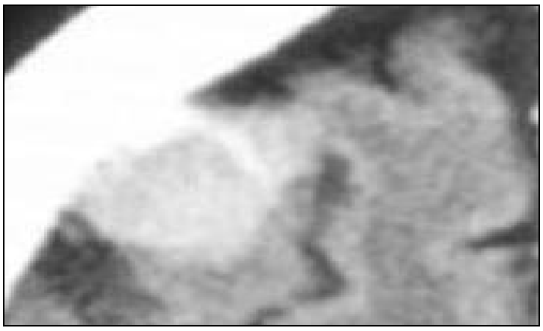

Fig. 5. The ROI of CT image

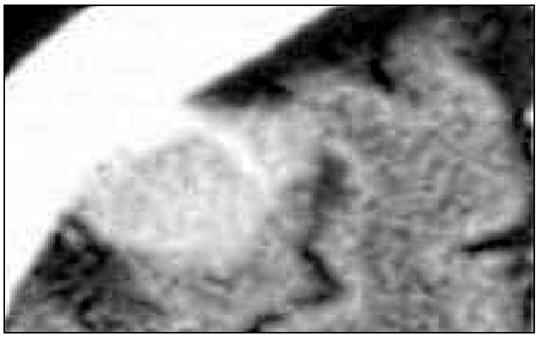

Fig. 6. The ROI of CT image with increased contrast

Fig. 7. The ROI of CT image after Gaussian noise reduction

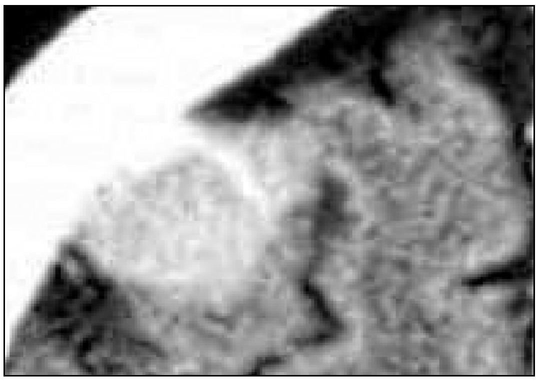

Fig. 8. The ROI of CT image after Poison noise reduction

4. CONCLUSION

In the paper is proposed a new and effective approach for CT image enhancement and noise reduction of different type of noises. The complex processing has an effect of contrast enhancement, noise reduction and contours determination for selected ROI of different parts of diagnostic CT 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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