

One Application of Wavelet Packet Transformations for Medical Image Processing

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Abstract – The application of wavelet packet transformations in noise reduction cannot have only research disposition. The medical image quality must be preserved under the viewing conditions that are common in medical community. It's described in the paper a practical training of students from faculty of telecommunications and from faculty of computer systems in studying this problem by medical signal processing.

In the paper is presented a medical image filtering software and its graphic user interface (GUI). It works in the MATLAB environment and uses WAVELET TOOLBOXES defined functions. Different noise types and models can be used, regarding to different medical modalities of the images. The computer simulation can help the students to get deeper insight into effect of various factors such: type of wavelet packet functions, level of decomposition, adaptive shrinkage decomposition, founded with the respect to the entropy-based criteria, type of the threshold and its parameters by studying the wavelet transformations and their application in noise reduction.

The presented GUI is suitable also to real medical applications for noise reduction in different type of images.

Keywords – Noise reduction, wavelet packet transformation, thresholds methods, graphic user interface, and computer simulation.

I. INTRODUCTION

The wavelet packet methods for noise reduction give more complete analyses, which provide increased flexibility. They have the following important properties [1]:

- give 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;
- propose numerous decompositions of the image, that allows estimate the noise reduction of different levels of its decomposition;
- allow adaptive denoising on each level of the decomposition by choice of optimal decomposition tree and optimal thresholds parameters.

The wavelet transformations present circumstantially the short time differences of the signals, including a noise, too.

It's made a trial in the paper to present some special features of the wavelet 2-D packet transformations, which can

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help by studying of the optimally strategy to eliminate a noise spectrum components by different medical modalities images.

The paper presents an application and GUI for filtering of different medical modalities images. An adaptive wavelet filtering can be realized on the base of adaptive shrinkage decomposition by using of global or penalized thresholds. By determination of the threshold is used the strategy of Birge-Massart [2]. This strategy is flexibility and allows to determinate the threshold in three directions: horizontal, vertical and diagonally. In addition the threshold can be hard or soft [3]. The software is created in MATLAB 6.5 environment by using WAVELET TOOLBOX.

The graphic user interface consists of checkboxes, buttons, edit boxes, pop-up controls, which make it easy to use. Users enter or choose input data in a single form, because input information changes and visualizations are easier and faster in this way.

The applied algorithm calculates also some objective quantitative estimation parameters. On the base of their analysis can be realized more precise noise reduction in different medical modalities images.

II. PROBLEM FORMULATION

At the university level, the material studied becomes more abstract and more mathematical. The students need to make some experiments as an introduction to the real experiment, with the goal to choose the parameters of the variables freely. It can be realized with the help of computer simulation by investigation of the process to noise reduction in different medical modalities such as: ultrasound (US), X-ray, computed tomography (CT) and magnetic resonance (MRI) images. In many case its quality can gives real information about the results of different therapy methods such as: magnetic field, laser [4] etc.

Let is presuppose, that the noise is received by transmission during communications systems. As result the medical image is received with a Gaussian white noise $e(n)$. The basic model of the input signal is given in (1) [5].

$$s(n) = f(n) + e(n) \quad (1)$$

So on the base of computer simulation we can formulate the following problems:

- To reduce the noise in input image with 2-D digital wavelet packet transformations.
- To study the effect of the type of wavelet packet function in noise reduction process.
- To study the effect of level of decomposition by noise reduction.

- To chose the adaptive shrinkage decomposition (best tree) on the base of the best level and minimum of the entropy criteria.
- To study the effect of type of the threshold by noise reduction.
- To study the effect of the parameter α for the circumstantially coefficients.

The results of simulation can be presented in quantity and visually estimates. Following objective quantitative estimation parameters can be used: 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) [6].

III. THE GUI FOR MEDICAL IMAGES FILTERING

The Fig.1 shows the development GUI for filtering of medical images, based on discrete wavelet packet transformations (DWPT), and created in MATLAB environment. It is divided in several areas, where the user applies different settings, concerning noise and wavelet packet transformations.

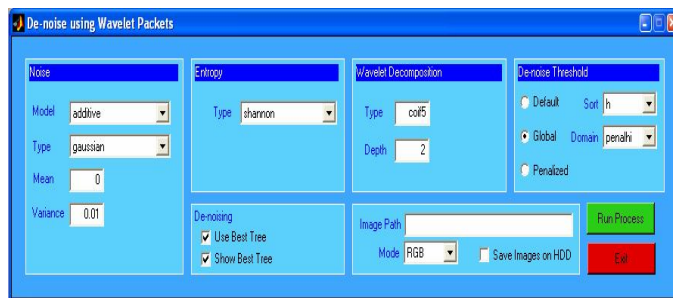


Fig. 1. The GUI for medical images filtering, based on DWPT

The area “Image Path” is for entering an image file name, but without an image file extension. For example, if the file name is “cp1.jpg”, the user should write “cp1”. The image file for de-noising must be in the same directory (folder), where the main program and the rest modules are. The image processing is made in two modes – RGB and YUV, chosen through the pop-up menu, default value is RGB [7]. The processed images (noised and denoised) can be saved on the hard drive (to the file name is added „-nR”, “-dnR” for RGB mode and „-nY”, “-dnY”, “-dnYR” for YUV mode).

The area “Noise” is presented in Fig.2. There are given the default values for different noise type and models. It's chosen the Gaussian noise by default having Mean=0 и Variance=0.01. 'Mean' is the middle value and the 'Variance' characterizes the distribution.

The selected noise is applied to the image. The purpose is to simulate a real noise in a real situation.

The wavelet decomposition settings are selected in area “Wavelet Decomposition”, shown in Fig.3.

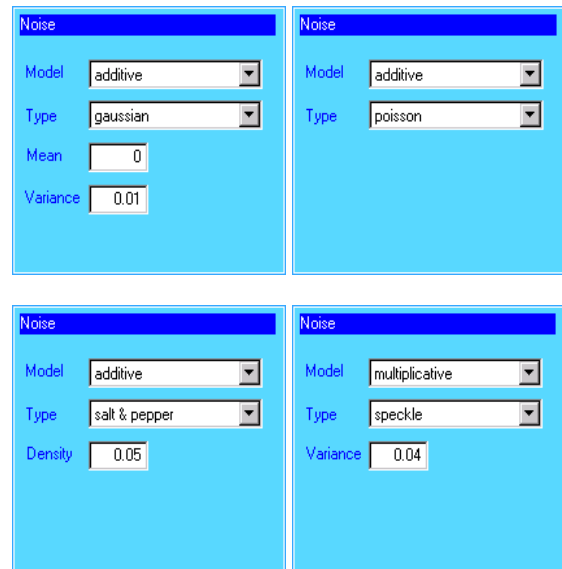


Fig. 2. The area “Noise”

Two parameters can be selected: the 2D packet wavelet function and the depth of decomposition. The type of the wavelet packet function can be selected from many families of functions, depending of the concrete application. The family of the orthogonal wavelet functions is a most suitable for this application. It includes the following functions: Daubechies, Symlets and Coiflets.

The decomposition depth must be positive integer.

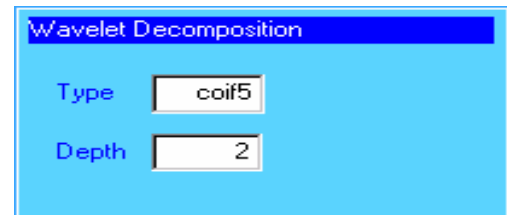


Fig. 3. The area “Wavelet decomposition”

For realizing an adaptive filtration can be selected a principle for making an adaptive shrinkage decomposition, given in Fig. 4 (Area “Entropy”). It can be founded with the respect to the entropy-based criteria. Three types of entropy criteria can be selected: Shannon, norm and log energy. According to the minimizing entropy criteria some certain (unnecessary) nodes from the decomposition tree can be removed.

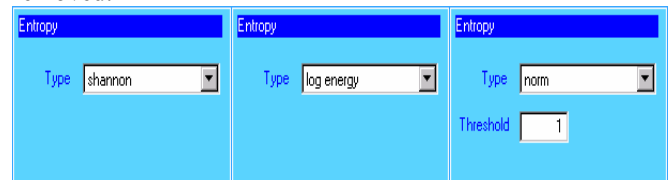


Fig. 4. The area “Entropy”

The method of denoising, that can be chosen is shown in Fig. 5 with the area “Denoising”. Using the adaptive shrinkage decomposition (best tree) for the wavelet decomposition is very important in getting a good result from

the denoising. It is defined by the kind of the wavelet function for decomposition, the depth of the decomposition, and the entropy criteria. In case, that the user doesn't want to use the "best tree" in the algorithm for calculating the threshold and subsequently in denosing, he can see the initial tree. When 'Use Best Tree' is not checked, the label 'Show Best Tree' is transformed to 'Show Initial Tree' and the result is visualizing the whole tree limited according to the selected depth.



Fig. 5. The area "Denoising"

Selecting appropriate threshold is an important part in denoising of medical images. Giving the determinate threshold of the level and breaking on level the circumstantially coefficients, can be reduced also the level of the noise. But the most interesting aspect of this problem is that the level of limitation can be determinate separately for every one coefficient. This permits to make adaptive changes of the signal. The user can select the threshold in the "De-noise threshold" area, presented in Fig.6. There are three types of thresholds – default, global and penalized with parameter alpha, which is a floating value. The threshold is applied to the wavelet coefficients. They become equal to zero if their value is smaller than the selected threshold, and the bigger coefficients are processed according to the threshold's type – soft ('s') or high ('h').

The default threshold is not effective because it removes too many components from the usefull part of the signal, so the result is a very blurred image. It has much great value in comparison to the other two thresholds. The 'Global' threshold is much more effective than the 'Default'. It is applied globally to all wavelet coefficients calculated by the wavelet decomposition. It is defined by the values for penalhi, penalme и penallo, which corresponds to three of the 'alpha' values – 6.25, 2 и 1.5. Increasing alpha makes the wavelet packet presentation of the denoised image worse. Experimentally is discovered that the 'Penalized' threshold is the most effective.

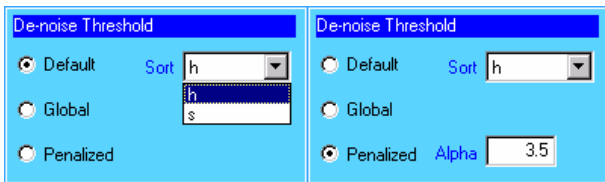


Fig. 6. The area "De-noise threshold"

After choosing all input information the procedure of denoising begins, when the user clicks on button 'Run'. Then the final result is shown – original image, noised image and de-noised image. When button 'Close' is pressed the user is asked whether he wants to quit the program. If he chooses

'Yes', the program can be closed, if he chooses 'No', he continues working with the program.

IV. EXPERIMENTAL PART

The simulation is realized by program environment of MATLAB 6.5 with using the Wavelet Toolbox.

By the experiments is used a sample image of size 450x500 pixels, given in Fig.7 which is leaving from MRI apparatuses and presented a bone disease.



Fig. 7. A sample MRI image

The best results by noise reduction of Gaussian white noise (Mean=0 и Variance=0.01) are obtaining by Coiflet wavelet packet functions, adaptive shrinkage decomposition (best tree) on the base of the second level and minimum of the Shannon entropy criteria, by using of hard penalized threshold. Fig.8 presents the adaptive shrinkage decomposition on level 2 for the processed MRI image.

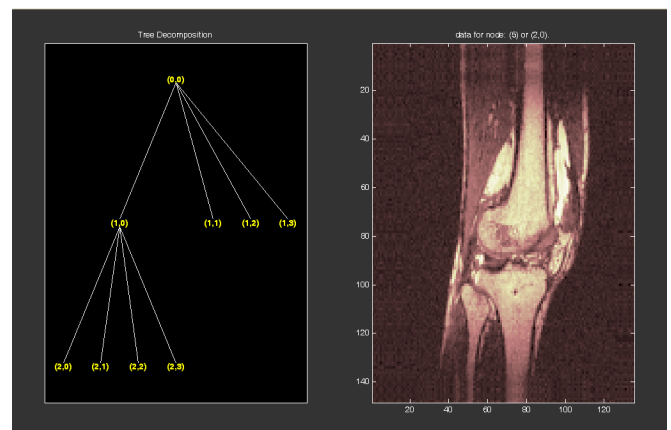
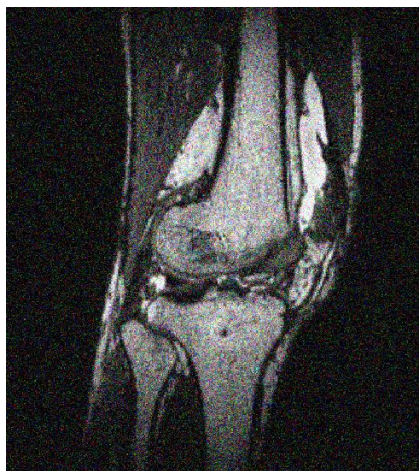


Fig. 8. Adaptive shrinkage decomposition on level 2 for the processed MRI image

Some results of simulation are presented in Table 1.

TABLE I
EXPERIMENTAL RESULTS FROM SIMULATION

Color system	Type of threshold	CNR	SNR _Y [dB]	SNR _R [dB]	E _{ff} [dB]
R	hard	0.3967	5.5595	5.7739	0.2144
G	hard	0.3931	5.6078	5.7893	0.1815
B	hard	0.3899	5.8553	6.0174	0.1621
Y	hard	0.6351	7.7001	7.9847	0.2846
U	hard	0.0328	4.5401	4.7753	0.2352
V	hard	0.0362	4.4538	4.6234	0.1694
R	soft	0.3999	5.5308	5.5595	0.0287
G	soft	0.4023	5.5529	5.6078	0.0549
B	soft	0.4010	5.7981	5.8553	0.0572
Y	soft	0.5806	7.6534	7.6971	0.0437
U	soft	0.0326	4.7717	4.7932	0.0216
V	soft	0.0318	4.6228	4.6829	0.0601



a)



b)

Fig. 9. Processing of simple MRI image:
a) noised MRI image; b) denoised MRI image, based on DWPT

The filtration is more effective by processing in YUV system, the averaging values of CNR in this color system are 0.21(in RGB system CNR=0.39). This shows that the noise is five times reduced.

The visually results from simulation of noise reduction are given in Fig.9. It presents the noised simple MRI image and denoised image, based on wavelet packet transformations.

V. CONCLUSION

The problem about application of the wavelet packet transformations cannot have only research disposition. A described in the paper practical training can be used successful in education for studying a medical image processing. The MATLAB environment makes possible to take many experiments by reduction of different type of noise in medical images. The presented GUI and the realized computer simulation can help the students to get deeper insight into effect of various factors by studying the wavelet packet transformations and their application in noise reduction.

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