Parametric Optimization in Noise Reduction of Medical Diagnostic Signals

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Abstract – **The telemedicine systems must deliver a high level of diagnostic quality and that quality must be preserved under viewing conditions that are common in the medical community. Some properties of the Wavelet Transforms are analyzed in the paper as a base for optimal strategy for elimination of noise spectrum components in the case of 2D-diagnostic medical signals. A possibility for parametric optimisation in noise reduction of real medical signals and their restoration has been tested using computer simulation in MATLAB environment. The paper can be used in engineering education in studying this process.**

Keywords – **Telemedicine, medical diagnostic signals, restoration of signals, noise spectrum, wavelet transforms, computer simulation.**

I. Introduction

The medical imaging technologies exploit the interaction between the human anatomy and the output of emissive materials or emissions devices. These emissions are then used to obtain pictures of human anatomy. The most popular technologies are ultrasound, x-rays, x-ray computed tomography and magnetic resonance imaging. These images provide important anatomical information to physicians and specialist upon which can be made diagnoses[5].

The medical signals have different characteristics and are not well matched to the type of natural images that motivate much of the research in telemedicine systems. The Wavelet representation provides a multiresolution – multifrequency expression of signal with localization in both time and frequency.

The Wavelet Transforms present circumstantially the short time differences of the signals, including the noise, too [3,4].

In image processing can be used effective methods in reduction of the noise components.

The program environment of the MATLAB version 6.0 or 6.1 with using the Wavelet Toolbox make possible a practical realization of the difficult Wavelet Transforms [1]. It can be realized computer simulation by investigation of the process to noise reduction of the real medical diagnostic signal. This noise is received by the transmission of 2D-signals during communications systems.

The simulation make possible to trail the process of optimization of some parameters as level of decomposition of the signals, type of the wavelet, parameters of threshold by the noise reduction.

II. Theoretical Aspects of the Problem

One of the basic concept in Wavelet Transforms is to present the signal with two components:

- a broad approximated component
- a precise approximated (circumstantially) component

and graining with the goal to chance the level of decomposition of the signal. This is possible in time and frequency domain, too.

Let the energy of the signal $s(t)$ is $\int_R s^2(t)dt$, limited in the space V, in limited domain R. Continue Wavelet Transform (CWT) of the signal can be assigned in analogy with CFT by calculation of the wavelet coefficients in Eq. 1

$$C(a,b) = \int_{-\infty}^{\infty} s(t)a^{-1/2}\Psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

Or in limited domain R in Eq. 2

$$C(a,b) = \int_R s(t)a^{-1/2}\Psi\left(\frac{t-b}{a}\right)dt\ , \qquad (2)$$

where $\Psi(t)$ is created from basic function $\Psi_0(t)$, and determined the type of the wavelet. It must provide the implementation of following operations:

- a translation in the time axis -$\Psi_0(t-b)$ when $b \in R$
- a scaling packet $a^{-1/2}\Psi_0\left(\frac{t}{b}\right)$ by $a\rangle 0$, where a gives the width of the packet; b gives the place

or in Eq. 3

$$\Psi(t) = a^{-1/2}\Psi_0\left(\frac{t-b}{a}\right) \qquad (3)$$

where b gives the place of the wavelet function and a gives the scaling of the function.

By image processing must be worked with 2D data.They can assigned in the space V, but as function of two variability.

By digital value of a and j, wavelet function can be presented in Eq. 4

$$\Psi_{j,k}(t) = a_0^{-j/2}\Psi(a_0^{-j}t-k) \qquad (4)$$

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And DCWT in conclusive description with digital value of a and b is given in Eq. 5

$$C(j,k) = d_{j,k} = \int_{-\infty}^{\infty} a_0^{-j/2}\Psi(a_0^{-j}t-k)s(t)dt\ , \quad (5)$$

where $C(j,k) = d$, are circumstantially coefficients of the wavelet decomposition of the signal on level k. For 2D DCWT the circumstances of discretisation are given in Eq. 6.

$$\begin{array}{l}(j,k)\in \mathrm{Z}^2,\ a=2^j,\ b=k2^j \\ \Psi_{j,k} = 2^{-j/2}\Psi(2^{-j}V-k)\ , \Phi_{j,k} = (2^{-j}V-k)\ .\end{array} \quad (6)$$

In Wavelet Toolbox the following theoretical methods are realized:

- time domain analysis
- frequency domain analysis
- multiresolution analysis

With help of the corresponding functions, the approximated coefficients A_j of the signal and the circumstantially coefficients D_j on the level j are computed. This representation of the signal is called decomposition of the signal on the level j. The output signal is the signal with the zero mean level of decomposition.

The following algorithm can be used:

1. Computing of circumstantially coefficients in Eq. 7
$$D_j(t) = \sum_{k\in Z} C(j,k)\Psi_{j,k}(t) \quad (7)$$
2. Computing of the signal as sum of his components in Eq. 8
$$s = \sum_{k\in Z} D_j \quad (8)$$
3. Approximation on the level $J - A_j = \sum_{j>J} D_j$
4. String between A_{j-1} and $A_j - A_{j-1} = A_j + D_j$
5. Some decompositions: $s = A_j + \sum_{j\leqslant J} D_j$

So, every level of decomposition of the signal can be represented in Eq. 9

$$\begin{array}{l} S = A_1 + D_1 \\ S = A_2 + D_2 + D_1 \\ S = A_3 + D_3 + D_2 + D_1 \\ S = \ldots\ldots\ldots\ldots\ldots\ldots \end{array} \quad (9)$$

If look at Eq. 9 as tree of reconstruction, so it will be exact of the apex. The precision of the reconstruction decreases in downhill. But the spectrum of the signal is narrow band. That means the filtering of the signal and decreasing size of information that is necessary for reproduction of the signal.

In noise reduction with Wavelet Transforms is used another method - the limitation of the level of circumstantially coefficients. The short-time speciality of the signal includes the noise components, which content many fortuitously deviations from the meaning signal. Giving the determinate threshold of their level and breaking on level the circumstantially coefficients, can be reduced the level of the noise, too. 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.

III. Experimental Part

Magnetic resonance imaging (MRI) is fast becoming the preferred modality in clinical applications, because it is minimally invasive and can be applied to both hard structures and soft tissues. MRI is based on measuring magnetic properties of hydrogen nuclei [2].

For experiment is using a real MRI of the liver with size 256 by 256 pixels, in JPEG format. Let is presuppose, that the noise is received by transmission during communications systems. As result the signal is received with a Gaussian white noise $e(n)$. The basic model is given in Eq. 10 [1].

$$s(n) = f(n) + e(n) \quad (10)$$

The proceedings to noise reduction consist of 3 stages:

1. Wavelet scanning of the signal on level N. It is made a choice of the type of the wavelet and the level of decomposition, where $N > 0;\ N = 2^n$
2. Circumstantially. For every level, from 1 to N can be choice a definite (hard) threshold and a corresponding (soft) threshold for the circumstantially coefficients
3. Restoration of the signal. Wavelet restoration is based on the output coefficients for approximation on the level $N$and modification of the circumstantially coefficients on level from 1 to N

The simulation makes possible to study the effect on three parameters:

- level of decomposition
- parameter ALPHA, to key the hard threshold for the circumstantially coefficients
- type of the wavelet

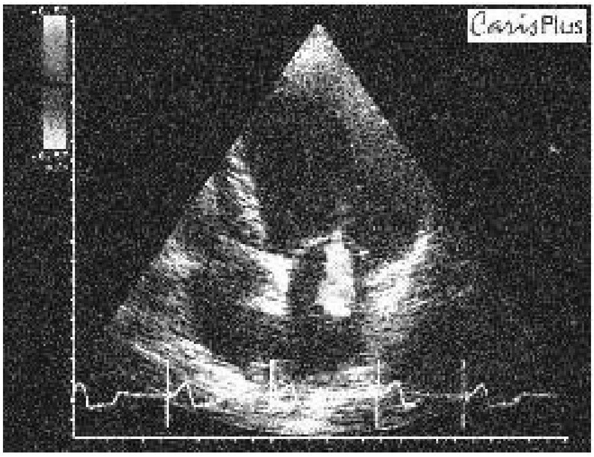
The result of simulation is given in Fig. 1.

On the base of experiments for the parametrical optimization in noise reduction of the 2D signal can make the following concrete conclusions:

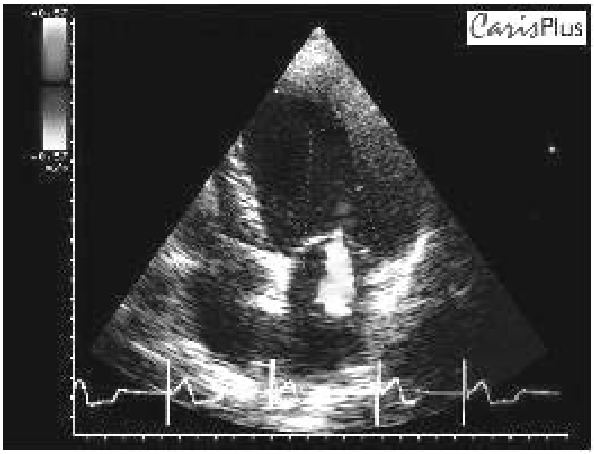
1. The using in Wavelet Toolbox in MATLAB functions give a good results in noise reduction of MRI signal.

2. The parameter ALPHA must be a full date>1 and the best result can be obtained when ALPHA≥3

3. By reconstruction of the signal, the basic effect is on the level of decomposition in comparison with type of the wavelet. For the using MRI, $N \leq 8$. Not for all type of wavelet the Converse Wavelet Transforms are possible.



Noised MRI



Denoised MRI

Fig. 1.

4. The threshold of decomposition is realized in three directions: horizontal, vertical and diagonally.

5. The number of level on decomposition is important for the converse transform of the signal. How much it is bigger, the image is unclear. It is received a losses not only in noised as in the original signal. In this case the full restoration of the signal is impossible. For that reason is necessary to search to optimal level of decomposition of the signal.

IV. Conclusions

The parametrical optimization in noise reduction of MRI is a trial to demonstrate the application of Wavelet Transforms by 2D diagnostic medical signals. The MATLAB environment makes possible many experiments with simulation of different type of noise.

They are given as test noise signals in Wavelet Toolbox.

The experiment is realized for MRI, but it can be used successful in case of ultrasound images, x-rays images and xray computed tomography, given a special feature of this signals.

Not of last place can be noticed, that the experiment is expedient for transmission of the signals in Internet. The preliminarily processing of the images with the goal to high level of quality is very useful in succeeding compression by teleconferencing and multimedia systems [6].

The parametrical optimization in noise reduction cannot have only research disposition. It can be used successful in education for studying this problem.

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