An Adaptive Approach for Magnetic Resonance Images Enhancement after Magneto - Therapy

Veska M. Georgieva, Dimiter Tz. Dimitrov
Faculty of Telecommunications, Technical University of Sofia, Bulgaria
1000 Sofia, "Kl. Ohridsky" str.8
E-mail: vesg@tu-sofia.bg,
dcd@tu-sofia.bg

Abstract

In this paper a complex post processing of magnetic resonance (MR) images from the bone structures after magneto therapy that combines different methods for image enhancement is presented. This includes increasing of brightness and contrast of the image, following by noise reduction on the base of 2D wavelet packet transformation. An adaptive threshold estimation method for image denoising in the wavelet domain is used, based on combination of threshold strategy of Birge-Massart and Normal Shrink method for modeling of detail sub-band coefficients. As next stage is proposed morphological filtering of the processed image. That allows detail preservation and contours determination of the investigated object. By choosing of top & bottom hat filtration and suitable form of structuring element, local geometry of the investigated object can be modified for shape or contrast enhancement.

The algorithm was treatment by optimization of some parameters of the wavelet transformations and selecting of the suitable structuring element in morphological processing on the base of objective quantitative estimation parameters. The main goal is noise reduction and improving the quality of the diagnostic MR images.

Some results of the experiments are presented, which were made by computer simulation in MATLAB environment.

Keywords: MR images enhancement, morphological processing, noise reduction, wavelet packet transformations and magneto-therapy.

1. INTRODUCTION

It is well known that application of low-frequency magnetic field in medicine provides an analgesic and anti-inflammatory influence. It improves micro-circulatory processes and local blood circulation [1].Because of that magneto-therapy is a useful method for therapy for many diseases. For instance it is a very appropriate method in

the cases of surgical, orthopedics and trauma diseases as fractures, postoperative fistulas, infiltrations and others. The low-frequency magnetic field improves conditions for heal of the injured tissues and bone, promoting resorbtion of an inflammatory and traumatic edema, removing pain and itch. This is very important for old people and in the case of diabetics disease. The inductors of apparatus can be situated on the clothes or on the plaster in the case of fractures, immediately after the plaster setting is made. The low frequency magnetic field can be provided by apparatus for magneto-therapy. Some results of application of new Bulgarian apparatuses for magneto therapy MAGNET 89M [2, 3] in the case of trauma of knee (Figure1) are described in the paper. The apparatus has many programs for therapy on the base of microprocessor. The parameters of magnetic pulses are indicated permanently by a digital display.

Figure 1. Application of new Bulgarian apparatuses MAGNET 89M in the case of trauma of knee

The disposition of inductors and space configuration of magnetic field can be seen in Fig.2.

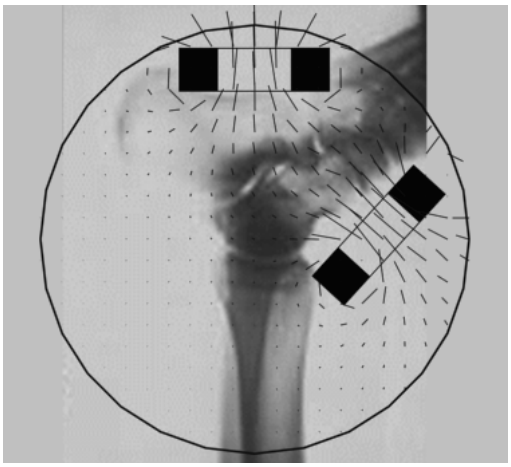


Figure 2. The disposition of inductors and space configuration of magnetic field

In MRI the practical limits of the acquisition time impose a trade-off between SNR and image resolution [4, 5]. The acquisition time is limited in practice due to patient comfort and physical limitations. Post-processing noise reduction is therefore often seen as only means of achieving a desired MRI image quality.

The conventional methods of filtration basic on the processing in spatial domain, can not give a high quality for the MRI images, which is needed for precise diagnosis. In [6, 7] are proposed wavelet (DWT) based denoising methods for MRI with simple soft threshold. In [8] is presented incorporating the coefficient propagation across scales in the form of multi-scale products and combining these multi-scale products with the spatial context.

In this paper is presented another approach (applied to investigation of bone structures), including histogram equalization and noise reduction on the basis of wavelet packet transformation (WPT). These methods can propose more complete analysis that provides increased flexibility. They have the following important properties:

- 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;
- Numerous decompositions of the image, that allows estimate the noise reduction of different levels of its decomposition;
- Adaptive noise reduction on each level of the decomposition by choice of best tree decomposition and optimal thresholds parameters.

An adaptive threshold estimation method for image denoising in the wavelet domain is used, based on combination of threshold strategy of Birge-Massart and Normal Shrink method for modeling of sub-band coefficients.

The next stage in algorithm is morphological processing. The morphological filters are used to image enhancement and detection of geometric structure of image objects. They are more suitable than linear filters for shape analysis and provides contrast enhancement in MRI by sharpening edges between homogeneous tissue regions and smoothing of noise within these regions.

Some quantitative estimation parameters, such as 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) have been analyzed in this paper [9].

2. BASIC STAGES OF THE ALGORITHM

2.1. Brightness enhancement

It has been proposed to modify MRI's histogram for enhancement of the brightness of this image. This approach proposed processing of the image in YUV system and equalizing the global histogram of its Y component [10]. So, this is a method to be obtained an even distribution of the brightness for all levels in the processed image.

2.2. Noise reduction on the base of 2D wavelet packet transformation

The main source of noise in MRI images is the thermal noise in the patient [11]. The MRI image is commonly reconstructed by computing the inverse discrete Fourier transform of the raw data [4]. The signal component of the measurements is present in both real and imaginary channels; each of two orthogonal channels is affected by additive white Gaussian noise.

The influence of the noise components is presented in the paper by an additive mathematical model.

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, the decomposition issued from given orthogonal wavelets can be determined. As this number can 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 [12].

Looking for best shrinkage decomposition to noise reduction, two important conditions must be realized together [13]. The conditions (1) and (2) are as following:

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

where E_K is the entropy in the level K for the best tree decomposition of 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 global threshold it is used the strategy of Birge-Massart [14]:

$$T = \left| \arg\min \left\{ -\sum_{k=0}^{t-1} d^2(k) + 2\sigma^2 t \left[\alpha + \log\left(\frac{n}{t} \right) \right] \right\} \right|, \quad for\ t = 1,2,...,n \tag{3}$$

and σ is estimated using the formula [15]:

$$\sigma = \frac{median(|W_i|)}{0.6745}, \tag{4}$$

where W_i are the wavelet packet coefficients in the sub-band HH_1 of the decomposition.

In Eq. (3) $d(k)$ are sorted in decreasing order of absolute value detail coefficients in wavelet packet decomposition; n - number of coefficients; σ - standard deviation of noise, calculated by Eq.(4) ; α - parameter, which can be [14]: $2,5 \le \alpha \le 10$.

This strategy is flexible. It uses spatial adapted threshold that allows determining the threshold in three directions: horizontal, vertical and diagonally. In addition the threshold can be hard or soft.

It is proposed to use in addition the Normal Shrink method to calculate the threshold value (T_N) only for the detail sub-bands in the best shrinkage decomposition. This threshold can be adaptive and calculated to different sub-band characteristics [16]:

$$T_N = \frac{\beta\sigma^2}{\sigma_Y}, \tag{5}$$

where the scale parameter β is computed once for each scale using the following equation:

$$\beta = \sqrt{\log\left(\frac{L_M}{J} \right)}, \tag{6}$$

where L_M is the length of the sub-band at M^{th} scale, J is the number of decompositions,

σ_Y is the standard deviation of the sub-band under consideration computed by using the standard MATLAB command.

2.3. Morphological processing

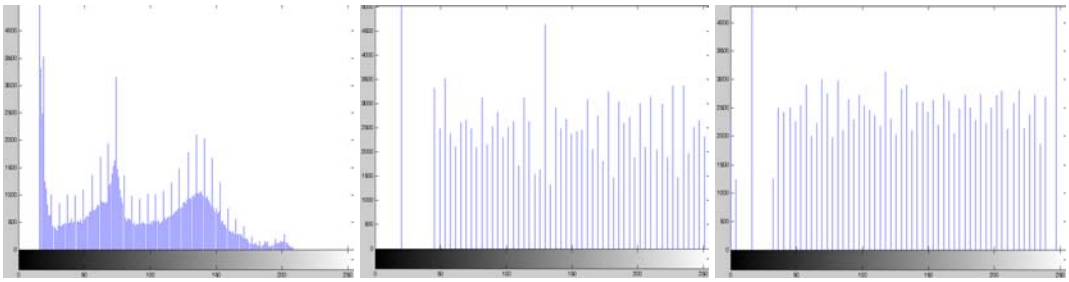
A morphological processing of the denoised MRI image has been proposed for detail preservation abilities. This stage includes morphological filtering by means of top & bottom hat operation [10]. It increases the contrast of the object by means of increasing the details in the dark regions and near by contours. The top and bottom hat filtering extracts the original image from the morphologically closed version of the

image. An investigation has been done for the influence of three different flat structuring elements (SE): line, disk-shaped and diamond-shaped with different sizes. The well-suited structuring element and its size for US images can be selected on the basis of some objective quantitative estimation: by minimum value for CNR and maximum values for PSNR and E_{FF} .

3. EXPERIMENTAL RESULTS

The formulated stages of processing are presented by computer simulation in MATLAB, version 6.5 environment with using the IMAGE PROCESSING and WAVELET TOOLBOXES. In analysis are used 20 MRI images with different sizes in cases of bone structures. The original images have been done in jpeg file format. All images are 24 bpp, in RGB system. By post processing they are converted in YUV system and bmp format.

Figure 3 presents histograms of Y component for MRI image of size 400x400 pixels. It illustrates the computed, equalized and the histogram after noise reduction on the base of wavelet packet transformation. The experimental results showed enhancement of the image and increasing of image information in consequence of brightness level restoration.



a) b) c)

Figure 3. Histograms of Y component of MRI image:

a) computed; b) equalized; c) computed after noise reduction

The obtained average results from the simulation are presented in Table 1.

Table 1. Simulation results of different methods for pre-processing of MRI image

Basic stages of processing	**PSNR [dB]**	**CNR**	SNR_Y **[dB]**	SNR_F **[dB]**	E_{FF} **[dB]**
Histogram equalization (HE)	19.2810	-	-	-	-
Noise reduction on	28.7106	0.2341	17.1141	19.5864	2.4723

the base of WPT					
Morph. processing	33.3765	0.3445	19.5864	20.9588	1.3724

The obtained results from the simulation show that the noise reduction on the base of wavelet packet transformation by using of adaptive threshold estimation method is an effective approach. In this case the selected value of the α - parameter is 3.5. By using of values bigger of 3.5 the noise reduction can by greater, but the images have bad quality. The values of PSNR and Effectiveness of filtration (E_{FF}) are significant and the value of CNR is about 0.2, and shows that the noise is about five times reduced.

In Figure 4 is presented the decomposition for noise reduction of the investigated image and corresponding image for node (1, 0).

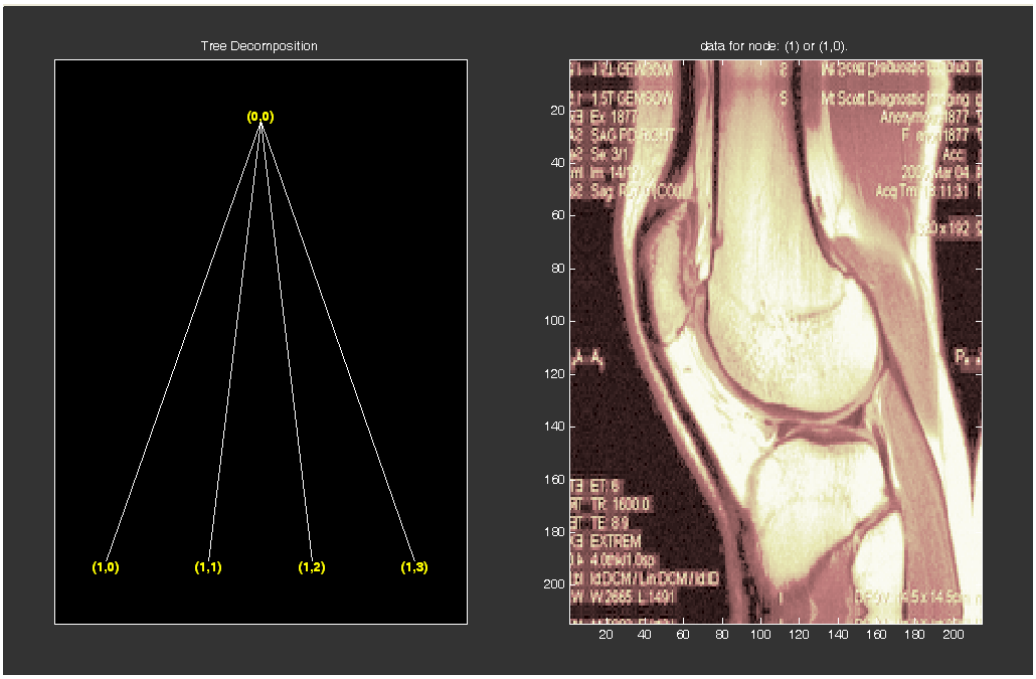


Figure 4. Wavelet decomposition and corresponding MRI image for node (1, 0)

The best results for morphological processing are obtained with the disk structuring element with radius R=3 by top and bottom hat operator. The values of PSNR and Effectiveness of filtration (E_{FF}) are maximum and the value of CNR is minimum (0.3), and shows that the additional noise is reduced by a factor of three. By using of line-shaped structuring element and especially a diamond-shaped structuring element can be obtained well-defined outlines of some tissues, but the values of the noised components in the image can be greater [10].

In Figure 5 are presented: the original MRI image, the processed image for brightness increasing and filtered image on the base of wavelet transformation and the image after following morphological processing.

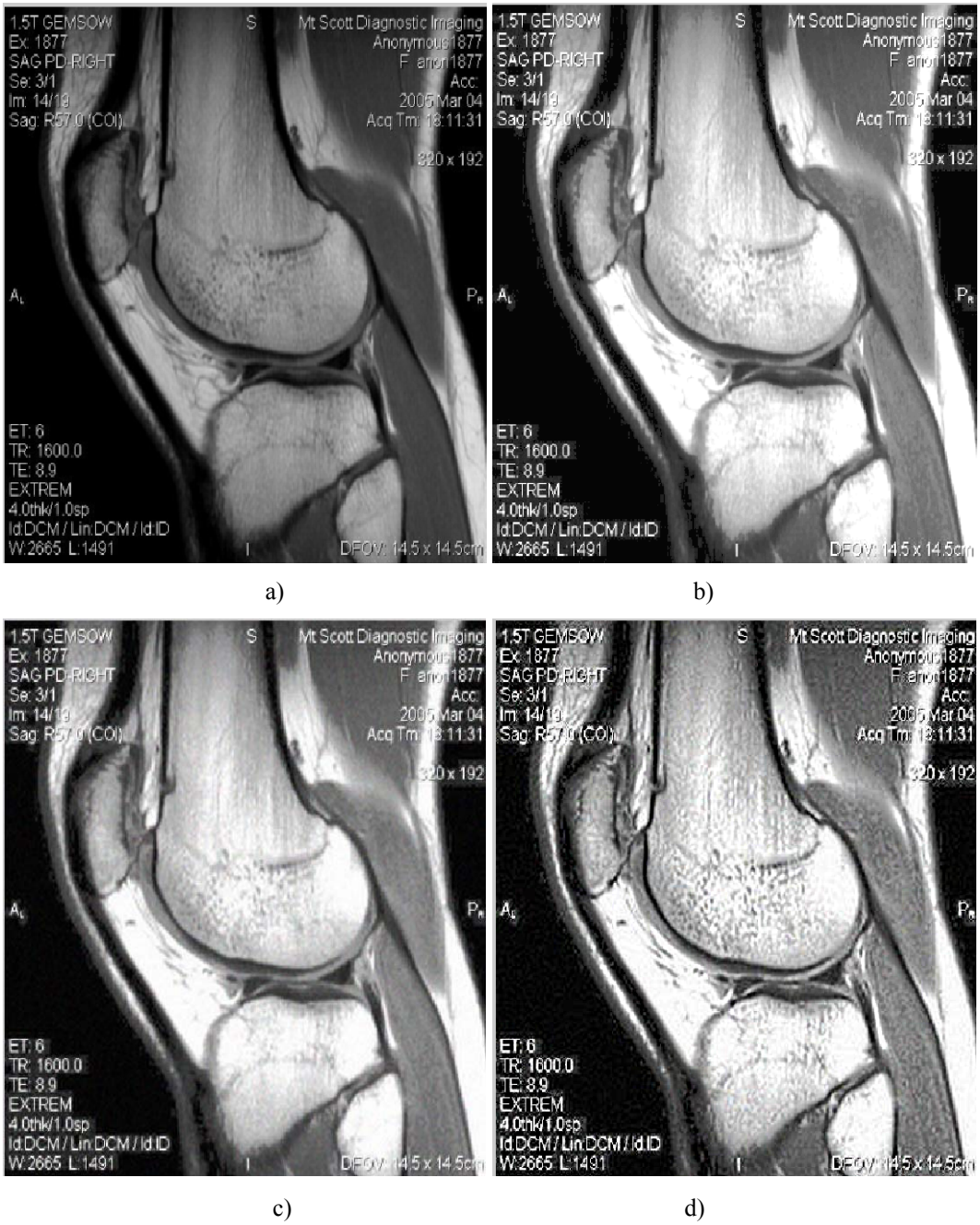


Figure 5. Original and processed MRI images:
a) the original image; b) image with increased brightness; c) filtered image; d) image after morphological processing.

The obtained results for noise reduction can be compared with other adaptive methods such as Wiener adaptive filtration (WAF) and 2D discrete wavelet transformation

(DWT). The obtained average results from the simulation of the MRI images are presented in Table 2.

Table 2. Simulation results of different methods for pre-processing of MRI image

Method of pre-processing	**PSNR [dB]**	**CNR**	SNR_Y **[dB]**	SNR_F **[dB]**	E_{FF} **[dB]**
HE + WAF with window 3x3	25.8373	0.6598	13.9090	14.8394	0.9304
HE+DWT	26.6193	0.5094	14.7085	15.8795	1.1710
HE+DWPT	28.7106	0.2341	17.1141	19.5864	2.4723

The graphical presentations of the obtained results for the three different methods are given at Figure 6, Figure 7 and Figure 8, respectively. At Figure 6 a diagram of CNR is presented, at Figure 7 a diagram of PSNR, and at Figure 8 a diagram of Effectiveness of filtration (E_{FF}).

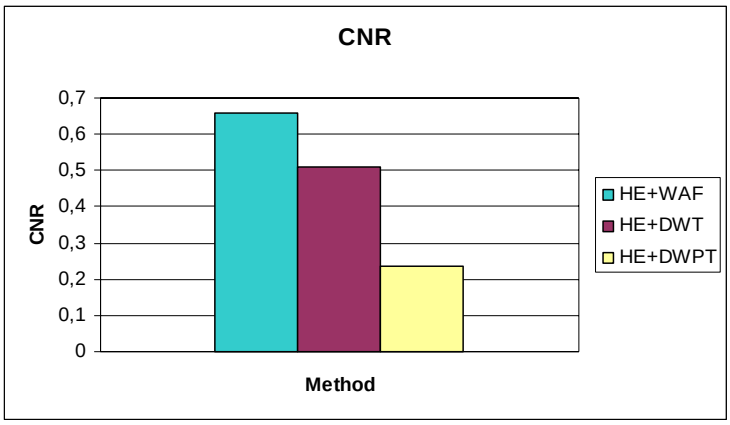


Figure 6. Diagram of CNR

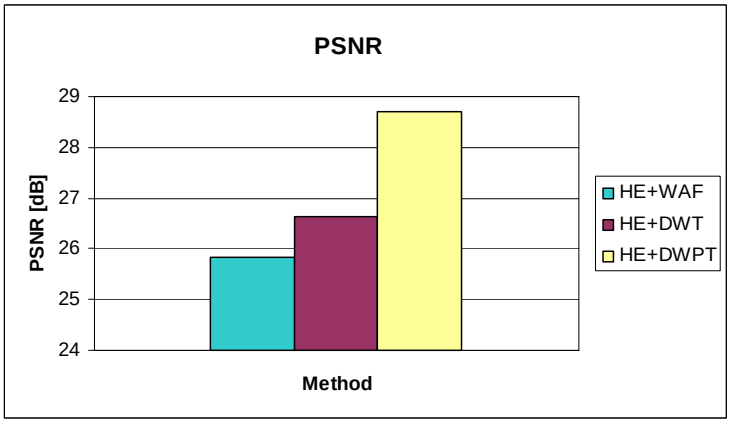


Figure 7. Diagram of PSNR

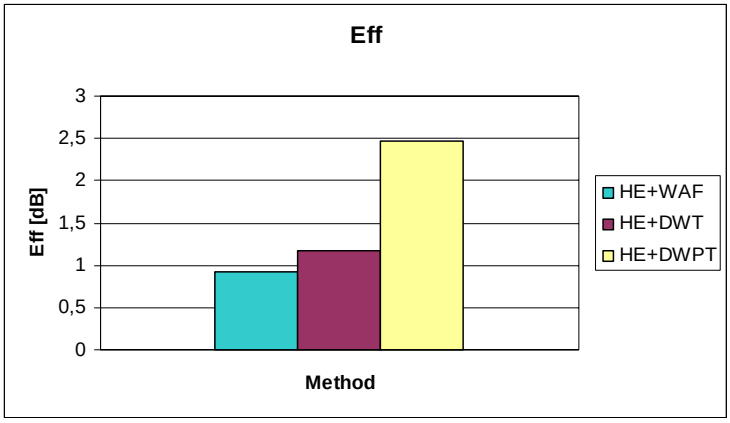


Figure 8. Diagram of CNR

The obtained simulation results show that the third method (HE+DWPT) is more effective. The value of CNR is about 0.2 and shows that the noise is reduced by a factor of five. The value of CNR by second method (HE+DWT) is about 0.5 and shows that the noise is reduced by a factor of two. The values of PSNR and Effectiveness of filtration (E_{FF}) for the proposed method are satisfactory.

5. CONCLUSION

A new and effective approach for MR image enhancement has been proposed in this paper. The complex processing has an effect of brightness and contrast enhancement, noise reduction on the basis of WPT and contours determination of objects in the MR images in cases of bone structures. An adaptive threshold estimation method for image denoising in the wavelet domain is used, based on combination of threshold strategy of Birge-Massart and Normal Shrink method for modeling of detail sub-band coefficients. The implemented investigation and obtained results by using real images attempt to make diagnoses more clear.

REFERENCES

[1] N. Todorov, Magneto Therapy, Sofia, 1994 (in Bulgarian).

[2] Apparatus for magneto therapy, UK Patent GB 2 188 238 B G01R 33/02, Patent published 22 Nov. 1989.

[3] Apparatus for Magneto Therapy, No. 106098/09.11.2001, Protective document BG 760 Y1, A 61 N 2/04.

[4] A. Macovski, “Noise in MRI”, Magnetic Resonance Medical, Vol.36, pp.494-497, 1996.

[5] E.R. McVeigh, R.M. Henkelman, M. J. Bronskill, “Noise and filtration in MRI”, Medical Phys., Vol. 3, pp.604-618, 1985.

[6] P. Bao, L. Zhang, “Noise reduction for magnetic resonance images via adaptive multiscale products thresholding”, IEEE Transactions medical imaging, Vol.22, pp.1089-1099, 2003.

[7] M. Jansen, “Noise Reduction by Wavelet Thresholding”, Springer–Verlag New York Inc., 2001.

[8] V. T. Maxim, L. Sendur, M. Fadili, J. Sucklimg, R. Gould, R.Howard, E. Bullmore, “Fractional Gaussian noise and functional magnetic resonance imaging“, Neuro Image, Vol.25, pp. 141-158, 2005.

[9] R. Gonzalez, R. Woods, “Digital Image Processing”, Addisson Wesly Publishing, 1992.

[10] V. Georgieva, A. Genova, “MRI enhancement on the base of morphological processing”, Proceedings of International Scientific Conference on Information, Communication and Energy Systems and Technology, Vol.2, pp.558-561, Nish, Serbia, 2008.

[11] M. Smith and A. Docef, Transforms in Telemedicine Applications, 2nd ed., Kluwer Academic Publishers, USA, 1999.

[12] R.Coifmann, M.Wickerhauser, “Entropy based Algorithms for best basis selection”, IEEE Transaction on information theory, Vol.38, pp.713-718, 1992.

[13] V.Georgieva, R.Kountchev, “An influence of the wavelet packet decomposition on noise reduction in ultrasound images”, Proceedings of International Scientific Conference on Information, Communication and Energy Systems and Technology, pp.185-188, Sofia, Bulgaria, 2006.

[14] MATLAB, User’s Guide, www.mathwork.com

[15] M. Vattereli, J. Kovacevic, Wavelets and Subband Coding, Englewood Cliffs, NY, Prentice Hall, 1995.

[16] L. Kaur, S., Gupta, R. Chauhan, “Image denoising using wavelet thresholding”, Journal of Medical Engineering Technology, Vol.29, pp.208-214, 2006.