METHOD FOR WATERMARKING OF MEDICAL IMAGES BASED ON FAST COMPLEX HADAMARD TRANSFORM

Rumen Parvanov Mironov

Assistant Professor
Technical University of Sofia, Faculty of Telecommunications,
Boul. Kl. Ohridsky 8, Sofia 1000, Bulgaria
Phone: 00359-2-965-22-74, E-mail: rmironov@tu-sofia.bg

Roumen Kirilov Kounthev

Professor, D.Sc.
Technical University of Sofia, Faculty of Telecommunications,
Boul. Kl. Ohridsky 8, Sofia 1000, Bulgaria
Phone: 00359-2-965-22-74, E-mail: rkountch@tu-sofia.bg

Abstract

In this article a new method for digital watermarking of medical images is proposed. The used approach is based on the modification of selected coefficients phases of their discrete spectrum obtained by applying of the developed by the authors' discrete 2D Fast Complex Hadamard Transform algorithm. The halftone image is divided into 16x16 sub-blocks and selected parts introduces digital watermark. The main advantages of the proposed approach to tagging images are the practical invisibility of watermarks in place, their resistance to change, compression with loss of information, affine transformations, trimming, contrasting, linear and nonlinear filtering, noising, and implementing other effects and manipulations.

The obtained results show that the developed method is especially suitable for medical imaging and databases, where information announces to be reliable, protected from external access and to reproduce with high accuracy.

1. INTRODUCTION

As a result of the widespread use of information and communication technologies, archiving and secure storage of large quantities documents in digital form is integral part of the modern life. For this reason, electronic archiving and authenticity protection of digital content is an important task for society in a number of priority areas such as administrative services to the population, health, financial and police service, judiciary, distance education, preserving cultural heritage, and others.

Usually the medical documents and images are stored in one of the popular formats such as JPEG, BMP, TIFF, PDF, PNG and others. Basic compression methods and algorithms used in these formats are associated with maintaining the visual quality of the images and their reproduction without losses. A disadvantage of this approach for storing of documents is that they may be edited, in result of which their authenticity is distorted. For important documents, the problems with their reliable storage in ensuring their authenticity are particularly significant. Typically, this protection is done using special methods and use of codes with high resistance, which can lead to a considerable increase in the volume of stored data. Therefore, the problems associated with archiving of medical documents are of particular relevance in the world and attract to a significant proportion of applied research in this area.

One possible solution is the use of digital watermarking, as a means of integrating hidden information in halftone images [1]-[6]. The watermark should be invisible to the viewer, resistant to attempts to delete it, have a large information capacity, can be read using a passkey on several levels, to introduce a minimum number of computing operations and extracted without the use of original product.

2. MATHEMATICAL DESCRIPTION

The coefficients of Complex Hadamard Transform matrix $[CH_N]$ with dimension N by N can be represented by the following equations [7], [8], [9]:

$$\left| \begin{array}{l} c(u,v) = j^{uv} s(u,v) \\ c^*(u,v) = (-j)^{uv} s(u,v) \end{array} \right. , \quad (1)$$

where: $N = 2^n$, $j = \sqrt{-1}$, u, v=0,1,…2^n-1 and

$$s(u,v) = \begin{cases} 1 & \text{for } n = 2 \\ (-1)^{\sum_{r=3}^{n} \lfloor u/2^{r-1} \rfloor \lfloor v/2^{r-1} \rfloor} & \text{for } n = 3,4,.. \end{cases}, \quad (2)$$

is the sign function. Here $\lfloor . \rfloor$ is an operator, which represents the integer part of the result, obtained after the division.

From the equations (1) and (2) the CHT basis matrix of order 2^n calculated for n=2 and *u,v* = 1,2,3,4 is presented as follows:

$$[CH_4] = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix}. \quad (3)$$

The basis complex Hadamard matrices of order *2^n* (n>2) can be received as the Kroneker product of a number of identical "core" matrices of order *2^{n-1}* in the following way:

$$[CH_{2^n}] = \begin{bmatrix} [CH_{2^{n-1}}] & [CH_{2^{n-1}}] \\ [CH_{2^{n-1}}] & -[CH_{2^{n-1}}] \end{bmatrix}. \quad (4)$$

The developed by the author's algorithm for Fast Complex Hadamard Transform (FCHT) use factorization of basis CHT matrices by the sparse matrices [10]. The complex Hadamard matrix $[CH_N]$ of order *N=2^n* can be presented by the equation:

$$[CH_N] = [CHJ_N] \prod_{r=1}^{n-1} [G_r(N)], \quad (5)$$

where: $n = \log_2 N$, $\lfloor G_r(N) \rfloor$ are the sparse matrices with two non-zero elements in each row, which have the following block-diagonal structure:

$$[G_r(N)] = \begin{bmatrix} [A(r)] & 0 & ..... & 0 \\ 0 & [A(r)] & ..... & 0 \\ ..... & ..... & ..... & ...... \\ 0 & 0 & ..... & [A(r)] \end{bmatrix}.$$

The sub-matrices $\lfloor A(r) \rfloor$ are defined as Kroneker product of the matrices:

$$\lfloor A(r) \rfloor = \lfloor H_2 \rfloor \otimes \lfloor I_{2^r} \rfloor, \quad (6)$$

where: $[I_{2^r}]$ is identity matrix of size $2^r x 2^r$, and $[H_2]$ is real basic Hadamard matrix of order 2.

Using definitions in (1) and equations (2)-(6) the fast forward one-dimensional CHT from the *N*-components input signal vector $\vec{A} = [a_1, a_2, ..., a_{N-1}, a_N]$, the output spectral vector - $\vec{B} = [b_1, b_2, ... b_{N-1}, b_N]$ is received by the equations [7]:

$$\vec{B} = [CHJ_N][G_1(N)][G_2(N)].....[G_{n-1}(N)]\vec{A}$$

or as a sequence of elementary transformations:

$$\begin{aligned} \vec{C}_1 &= [G_{n-1}(N)]\vec{A} \\ \vec{C}_2 &= [G_{n-2}(N)]\vec{C}_1 \\ &.......................... \\ \vec{B} &= [CHJ_N]\vec{C}_{n-1} \end{aligned}, \quad (7)$$

where: $\vec{C}_1, \vec{C}_2, ..., \vec{C}_{n-1}$ is the sequence of "intermediated" vector-iterations, which are received by the transformations with sparse matrices.

The developed FCHT algorithm can be illustrated by the signal flow graph for *N=4*, shown on Fig.1.

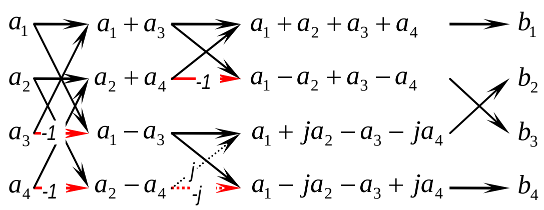

Fig. 1. FCHT signal flow graph of order 4.

The first matrix $[CHI_4]$ is presented with a first sub-graph and the second matrix $[CHJ_4]$ is presented with a second one in the generalized CHT signal flow graph. The third sub-graph presents reordering of spectrum elements. Multipliers are *+1* and *-1* as indicated by the black and red solid lines in real parts of sub-graphs and *+j* and *–j* as indicated by the black and red dashed lines in complex parts, respectively.

The described algorithm can be used for the reverse Fast Complex Hadamard Transformation. The flow graphs are identical and all output components must be divided on the *N*.

The FCHT algorithm is similar with the real FHT algorithm, which leads to considerable decreasing of mathematical computations. The difference between FCHT and FHT is entirely into the last iteration, which includes all complex operations.

3. EXPERIMENTAL RESULTS

The developed one-dimensional FCHT algorithm requires $N.\log_2 N$ additions or subtractions and *N/2* complex operations in the last iteration. Using the matrix descriptions for the 2D Complex Hadamard Transform in [8], the 2D FCHT algorithm can be realized by applying of 1D FCHT on the rows of the input image matrix and after then applying the 1D FCHT on the columns of the obtained matrix. The calculation complexity of 2D FCHT can be evaluated from the complexity of 1D FCHT and require: $2.N^2.\log_2 N$ additions or subtractions and N^2 complex operations.

The developed method for watermarking of medical images includes:

– viding of input image into sub-blocks of size 16x16;

– caulation of complex spectrum of each sub-block by the using of 2D FCHT;

– modification of the phase of some chosen complex-conjugated couple of spectrum coefficients by the approaches, described in [14].

– calculation of inverse 2D FCHT of each sub-block and writing the real part into the output image.

The developed method for watermarking of medical images by the using of FCHT was simulated on Matlab 6.5 environment for one X-Ray test image.

As a criteria for the watermark quality, evaluation for every image, could be used the signal to noise ration (SNR) of the watermarked image in respect to the original.

The obtained results proved the high efficiency of the watermarking with SNR>50 dB when the values of the watermark elements are in the range $\pm 3^0$ and are coded with 5 bits per element, missing the code 00000. In this case the maximum speed for watermark data transmission is approximately 860 bps.

To protect the digital content of medical images can be used scrambling of image elements in each sub-block and a law scan of scrambling to be recorded in the involved watermark. This leads to the practical impossibility of using the medical imaging from unauthorized persons.

As a sample on Fig.2 is shown one test image "Spine.tif", with watermark sequence "13 9 5 1 1 5 9 13 29 25 21 1 1 21 25 29", written in each sub-block and on Fig.3 is shown the same image with scrambling.

Fig. 2. Watermarked X-Ray test image

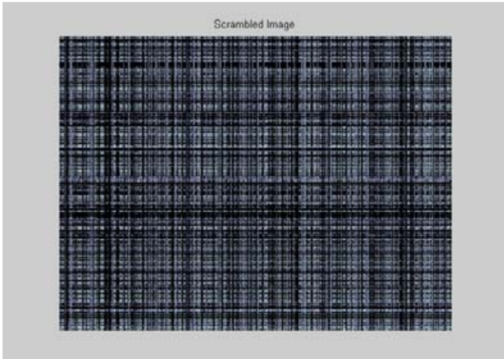

Fig. 3. Scrambled X-Ray test image

The scrambling was accomplished by the pseudo random reordering of rows and columns of each sub-block.

4. CONCLUSION

A new method for watermarking of medical images in the phase spectrum was developed. The method uses the developed Fast Complex Hadamard Transform algorithm. Advantage of the method is the fact that there is no quantization of the transform coefficients, the method has relatively low computational complexity and permits the insertion of different watermark with high information capacity in every sub-block of the images.

The method offers exact watermark extraction, high resistance against pirates' attacks with multiple lossy compression or different kinds of image transforms. The insertion of different watermarks in every sub-blocks makes the identification of the manufacturers and of the authorized distributors of multimedia production much easier.

The obtained results show that the developed method is especially suitable for medical imaging and databases, where information announces to be reliable, protected from external access and to reproduce with high accuracy.

5. ACKNOWLEDGMENTS

The authors thank the National Fund for Scientific Research of the Bulgarian Ministry of Education and Science for the financial support by the contract VU-I-305/2007.

References

[1] B. M. Planitz, A. J. Maeder. "Medical Image Watermarking: A Study on Image Degradation". *Proceedings of the Australian Pattern Recognition Society (APRS) Workshop on Digital Image Computing (WDIC 2005)*, Brisbane, Australia, 12 February 2005, pp.3-8.

[2] K. A. Navas, M. Sasikumar. "Survey of Medical Image Watermarking Algorithms", *4th International conference: Sciences of Electronic, Technologies of Information and Telecommunications*, Tunisia, March 25-29, 2007

[3] M. Kallel, M. S. Bouhlel, J. C. Lapayre. "A multiple Watermarking Scheme for Medical Image in Spatial Field". *ICGST International Journal on Graphics, Vision and Image Processing*, GVIP, 2007, vol.7, No.1, pp.37-42.

[4] C. Chemak, J. C. Lapayre, M.S. Bouhlel. "A new scheme of image watermarking based on 5/3 wavelet decomposition and Turbo-Code". *European Computing Conference (ECC'07*), WSEAS Transactions on Biology and Biomedicine, Vol.4, No.4, 2007, pp.45-52.

[5] C. Chemak, J. C. Lapayre, M. S. Bouhlel. "New Watermarking Scheme for Security and Transmission of Medical Images for Pocket Neuro Project". *Radioengineering*, Vol. 16, No. 4, December 2007, pp.58-63.

[6] Hui-fen Huang, "Perceptual Image Watermarking Algorithm Based on Magic Squares Scrambling in DWT", *2009 Fifth International Joint Conference on INC, IMS and IDC*, 2009, pp.1819-1822.

[7] B. Falkowski, S. Rahardja. "Complex Hadamard Transforms: Properties, Relations and Architecture", *IEICE Trans. Fundamentals*. Vol. E87-A, No.8, August 2004.

[8] R. Mironov, R. Kountchev. "Analysis of Complex Hadamard Transform Properties", *XLI International Scientific Conference on Information, Communication and Energy Systems and Technologies*, ICEST 2006, 26 June – 1st July, Sofia, Bulgaria, 2006, pp.173-176.

[9] R. Mironov, R. Kountchev, V. Mirchev "Ordered Complex Hadamard Transform of Images", *XL International Scientific Conference on Information, Communication and Energy Systems and Technologies*, ICEST 2007, Ohrid, Macedonia, June 24-27, 2007, pp.123-126.

[10] R. Mironov, R. Kountchev. "Algorithm for Fast Complex Hadamard Transform", *XLV International Scientific Conference on Information, Communication and Energy Systems and Technologies*, ICEST 2010, Ohrid, Republic of Macedonia, 23-26 June 2010.