An Enhanced Digital Watermarking for Health System

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ABSTRACT: *Digital water marking has been undergoing rapid improvements in technology enhancement. We in this work have proposed an algorithm that can help digital watermarking of health system images. We have also applied it with a signal processor and practiced in real-time system. In the experimentation we have found that it has produced better transparency and immune to a larger number of cyber-attacks. We have performed the trails on the base of evaluation of mean-squared error and signal to noise ratio of the reconstructed images.*

Keywords: Medical Image Watermarking, Wavelet Transform, DCT, Unitary Transforms, Matlab Simulation

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1. Introduction

Recent technological advances in Computer Science and Telecommunications introduced a radical change in the modern health care sector, including: medical imaging facilities, Picture Archiving and Communications System (PACS), Hospital Information Systems (HIS), information management systems in hospitals which forms the information technology infrastructure for a hospital based on the DICOM (Digital Imaging and Communication in Medicine) standard. These services are introducing new practices for the doctors as well as for the patients by enabling remote access, transmission, and interpretation of the medical images for diagnosis purposes [1], [2], [3].

Digital watermarking has various attractive properties to complement the existing security measures that can offer better protection for various multimedia applications [4]. The applicability of digital watermarking in medical imaging is studied in [5] and a further justification of the watermarking considering the security requirements in teleradiology is discussed in [2].

The new medical information systems required medical images to be protected from unauthorized modification, destruction or quality degradation of visual information. The other problem is a copyright protection of disseminated medical information over Internet. In this regard three main objectives of watermarking in the medical image applications: data hiding, integrity control, and authenticity are outlined in [5], which can provide the required security of medical images.

Every system for image watermarking is characterized with invisibility of the watermark, security of the watermark, robustness of the watermark and the ability for reversible watermarking. The importance of each depends on the application and how it is used [6], [7].

Based on processing domain, watermark techniques can be separated as watermarking in spatial domain, watermarking in frequency domain and watermarking in phase domain of the input signal. According to the way of watermark preprocessing, discern two groups of methods: the first one is when the watermark is transformed in the domain of the input image and the second one is when the watermark is not transformed in the domain of the input image. Another classification is based upon the transparency of the watermark into the input images - the watermark is transparent or non- transparent [8], [9].

The best way to test the watermark robustness is by simulating of unauthorized attacks. Unauthorized attacks are attacks against the integrity of the watermark. The msost used attacks are unauthorized removal, adding or detection of watermark. The removal and adding of watermarks are active attacks while the detections of watermarks are passive attacks.

An outline of the medical image watermarking field that uses various techniques to embed watermark data and utilize various functions to detect tampered regions is given below in the paper [10].

In the available literature, there have been various watermarking realizations using Matlab Simulink environment [11], [12], [13], [14] and etc. In all of them two-dimensional simulations of Discrete Cosine Transform (DCT) and / or Discrete Wavelet Transform (DWT) have been examined and individual solutions for different types of attacks have been considered. In these articles are discussed different implementations of watermarking algorithms using MATLAB Simulink environment based on DCT, DWT and combination of DCT&DWT transforms. Simulation results show that DWT is somewhat better than DCT but combination of these two transforms gives much better results than individual one.

In the present work a simulation model on Matlab Simulink environment of developed by the authors' algorithm for digital watermarking of medical images using Wavelet transform and DCT is described [15]. The emphasis in the development has been placed on the selection of the most suitable embodiment directed to applications in the medical field. This is extremely important with regard to the specifics of medical images and their use as was discussed at the beginning of the consideration.

The developed algorithm ensures high transparency of the watermark and is resistant to various types of malicious attacks. The obtained experimental results for some simulated attacks over the three test medical images are made on the base of evaluation of the mean-squared error and signal to noise ratio of the reconstructed images. The robustness of the watermark against some attacks are tested with the post processing of watermarked images by adding of Salt and Pepper noise, Gaussian noise, filtration with median filters and average filters. The developed on the MATLAB simulation model is experimented by the personal computer with 3.2GHz Core-i5 processor and specialized signal processor board - TMS 320C6713 DSK.

2. Simulation Model Description

The common block scheme of the new developed algorithm for digital watermarking is discussed in the article [15]. The principal block scheme of simulation model, representing the embedding of the watermark is developed using MATLAB Simulink environment and is presented in Figure 1.

The presented model was developed with standard modules from the Simulink library, which allows it to be used in the implementation on a signal processor boards of the TMS family. The most important blocks are:

- Subsystem "*DWT-IDWT*";
- Subsystem "*Watermarking*";
- Subsystem "*Evaluation*".

In the Subsystem "*DWT-IDWT*" the input image is decomposed into 3 levels via 2D DWT. The transformed by the 2D DCT image of the digital watermark is included in one of the three 2D DCT transformed blocks from the 3th level of the 2D DWT – LH3, HL3 or HH3. The choice of the watermark insertion block with size PxQ is based on the maximum of entropy, as is is described in [15].

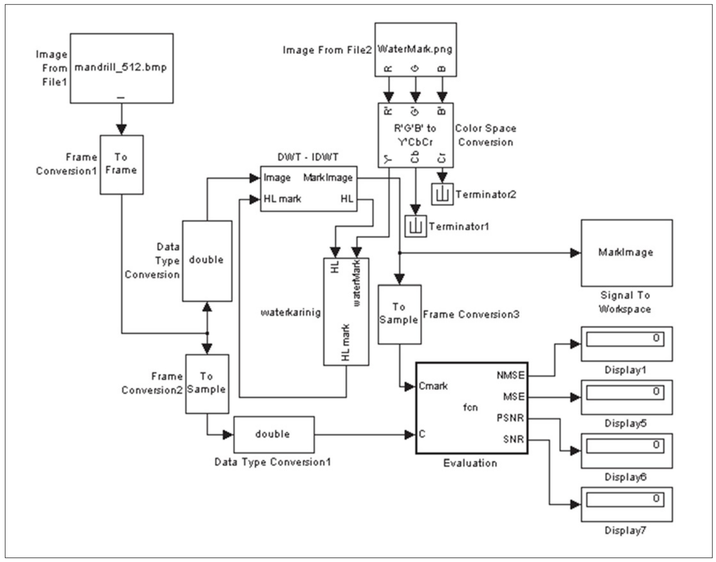

Figure 1. Simulation model, representing the embedding of the watermark

The Subsystem "*Watermarking*" is presented in Figure 2.

By means of the "*Auto threshold*" and "*Mark correction Block Processing*" blocks, the watermark coefficients are limited to the coefficients of the marker block in order to avoid oversaturation. The "*Resize*" block changes the size of the watermark to be suitable for tagging with the specified block, then DCT transformation is applied. The resulting values are multiplied by the marker depth coefficient ("*Constant*"). The DCT transformation is applied to the tag block. The two results were combined followed by reverse DCT transformation.

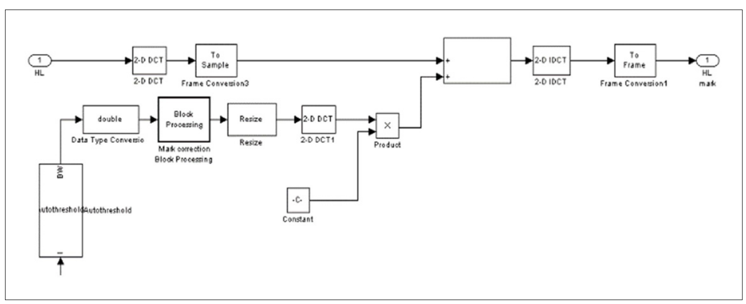

Figure 2. Simulation Subsystem "*Watermarking*"

The efficiency of the developed models for watermarking of medical images is estimated in the Subsystem "*Evaluation*" using the following metrics: peek signal to noise ratio (PSNR) estimate how transparent is the watermark to the human eyes; normalize cross-correlation (NC) is used to determinate how close the extracted watermark is compared to the original. High value of NC means that there are little differences between them; mean square error (MSE) and normalized mean square error (NMSE) are used to determinate how much the watermark image has change compared to the original.

The principal block scheme of simulation model, representing the extraction of the watermark is developed using MATLAB Simulink environment and is presented in Figure 3.

The developed decoder is informed. The transformed images - marked and original are including at the input. The purpose of the decoder is to determine what message (sign) is included in the watermarked image. The watermark is received in the reconstruction unit. Over the data received by the decoder applies inverse discreet wavelet transform. The most important blocks are:

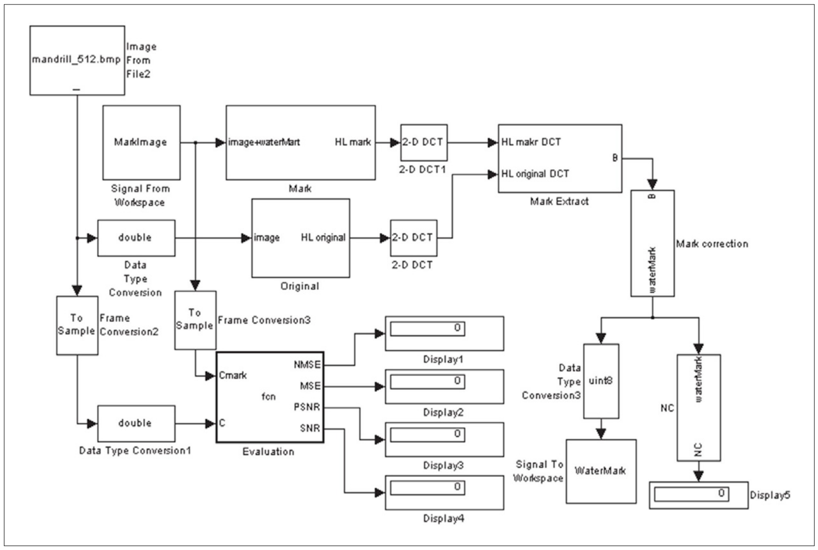

Figure 3. Simulation model, representing the extracting of the watermark

- Subsystem "*Mark*";
- Subsystem "*Original*";
- Subsystem "*Mark Extract*";
- Subsystem "*Evaluation*".

In the Subsystem "*Mark*", analogous to the encoder, a 2DDWT and extraction of the highlighted block is performed on the tagged images. In the Subsystem "*Original*", a 2D-DWT and extraction of the marker block is performed on a copy of the original image.

The Subsystem "*Mark Extract*" separates the watermark from the tagged fragment of the image using the marker depth coefficient ("*Constant*") and performs 2D-IDCT as is shown in Figure 4.

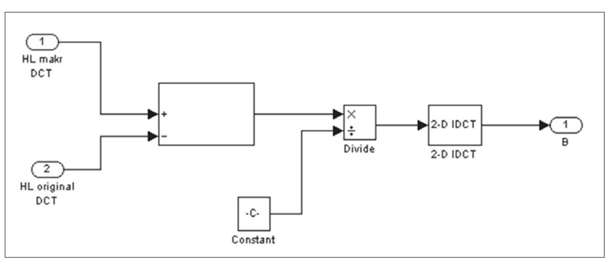

Figure 4. Simulation Subsystem "*Mark Extract*"

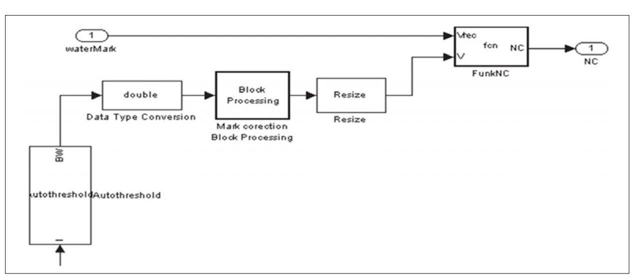

Figure 5. Simulation subblock "*NC*"

In the subblock “*NC*” the normalized cross-correlation is calculated using the formula given in [15]. The block is shown in Figure 5.

3. Experimental Results

For the analyses of efficiency of the developed model for watermarking of medical images three test images, shown in Figure 6a, b, c, with size 512x512 and 256 gray levels are used.

The test images shown in Fig.6 are transformed by the 3 levels DWT and the input watermark (letter *K*) is embedded into the transformed block (LLH) with maximum entropy of each image.

The robustness of the watermark against some popular attacks are simulated with the post processing of watermarked images by adding 100% of Gaussian noise with mean 0 and variance 0.01; adding 100% of Salt and Pepper noise; filtration with median filter with size 3x3; filtration of Gaussian noisy image with average filter; filtration of Salt and Pepper noisy image with median filter.

To estimating the efficiency of the developed models for watermarking of medical images the following metrics are used: peek signal to noise ratio (PSNR), normalize crosscorrelation (NC), mean square error (MSE) and normalized mean square error (NMSE) to determinate how much the watermark image has change compared to the original.

The results obtained from the tests shows that the efficiency of the developed in Simulink model with regard to watermark quality, its invisibility to the user and its resistance to some of the most commonly used attacks is the same as the program implementation developed by the authors and shown in [15]. The differences between the program implementation and the Simulink model appear only in the third decimal place (which represents an average of 0.004%).

Comparing the developed watermarking model with the existing ones in the literature, although the used images are different, the following conclusions can be drawn:

- The embedded watermark is practically invisible for the users and the visual quality of watermarked images is the same in the different publications;
- The coefficients PSNR, NMSE and NC are of the same order of magnitude for the various methods;
- The methods presented in the publications [11],[13] and [14] use frames of video sequences that are of inferior quality compared to those used in the article which demonstrates the advantages of the method described in the work;
- The described hybrid watermarking method (3 stage 2D DWT and 2D DCT) allows better resistance against most commonly used attacks.

Figure 6a. Input X-ray test image “Spine 1”

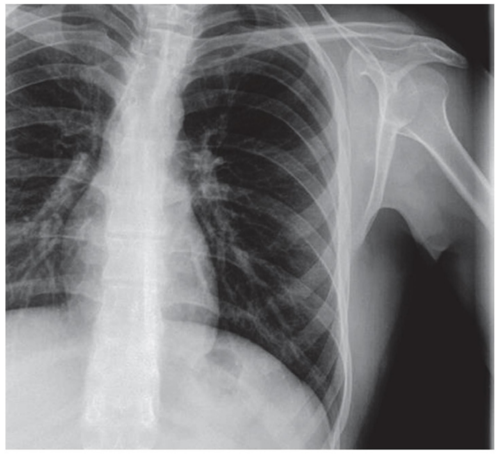

Figure 6b. Input X-ray test image “Spine 2”

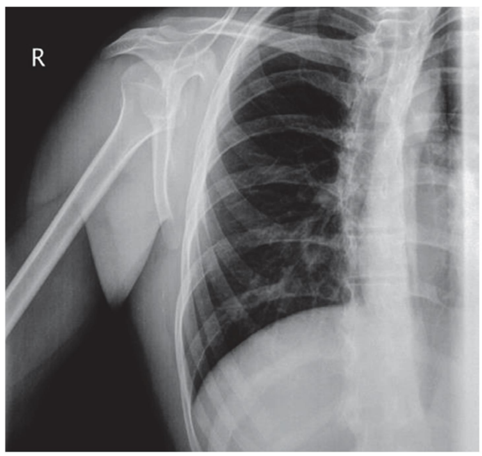

Figure 6c. Input X-ray test image “Spine 3”

The developed in the MATLAB Simulink environment model was tested on a personal computer with 3.2GHz Core-i5 processor and on a specialized signal processor board - TMS 320C6713 DSK.

The results, obtained from the simulation of Matlab, show that time coding for different images varies between 2.7 and 2.79 seconds. The biggest part of it is used for entropy processing and evaluation of the threshold for inserting watermark is about 2 seconds. Simulation on the signal processor TMS 320C6713 takes place over a real time scale, requiring about one second to load each image individually.

4. Conclusion

A simulation model for digital watermarking of medical images using Wavelet transform and DCT is presented. The obtained experimental results for some attacks over the three test medical images are made on the base of mean-squared error, signal to noise ratio and normalized cross-correlation of the reconstructed images. They shows that the developed model for watermarking allows high robustness to possible attacks based on image processing operations as transforms, filtrations and etc.

On the other hand the embedded watermark is practically invisible for the doctors and retains largely the information in the original images. This will allow to a great extent to verify the reliability of the medical data transmitted and recorded as images.

The developed watermarking algorithms and Matlab's simulations are comparable in quality and efficiency to the solutions described in the literature. In addition, experiments were performed with higher quality still images, indicating that the proposed solution could be used for more responsible tasks, for example in medicine, military, agriculture and cultural heritage.

All this leads to the conclusion that the developed models can be used successfully for watermarking not only of medical but on other type of data presented as images.

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