Wavelet Packets-Based Blind Watermarking for Medical Image Management

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Abstract: The last decade has witnessed an explosive use of medical images and Electronics Patient Record (EPR) in the healthcare sector for facilitating the sharing of patient information and exchange between networked hospitals and healthcare centers. To guarantee the security, authenticity and management of medical images and information through storage and distribution, the watermarking techniques are growing to protect the medical healthcare information. This paper presents a technique for embedding the EPR information in the medical image to save storage space and transmission overheads and to guarantee security of the shared data. This paper presents a new method for protecting the patient information in which the information is embedded as a watermark in the discrete wavelet packet transform (DWPT) of the medical image using the hospital logo as a reference image. The patient information is coded by an error correcting code (ECC), BCH code, to enhance the robustness of the proposed method. The scheme is blind so that the EPR can be extracted from the medical image without the need of the original image. Therefore, this proposed technique is useful in telemedicine applications. Performance of the proposed method was tested using four modalities of medical images; MRA, MRI, Radiological, and CT. Experimental results showed no visible difference between the watermarked and the original image. Moreover, the proposed watermarking method is robust against a wide range of attacks such as JPEG coding, Gaussian noise addition, histogram equalization, gamma correction, contrast adjustment, and sharpen filter and rotation.

1. INTRODUCTION

Recently, telemedicine applications in teleconsulting, telediagnoisis, telesurgery and remote medical education play a vital rule in the evolution of the healthcare domain [1]. The transmission, storage and sharing of electronic medical data *via* the networks have many purposes such as diagnosis, finding new drugs and scientific research. Hospitals and medical centers have huge databases including medical images, text and patient records. The exchange of these databases through the networks requires content management to index medical record information and a high degree of security and authenticity to preserve the privacy of the patients' information. To achieve these objectives, different techniques of digital watermarking have been employed. Ananad *et al.* [2] proposed a technique for watermark medical images with encrypted patient data in the spatial domain by swapping the lower significant bits of the gray values of chosen pixels of the medical image with that of the watermark. In [3], the encrypted patient information which is coded using error control codes is swapped with the least significant bit (LSB) of the grey scale image. Nambakhsh *et al.* [4] presented a watermarking method

combined with the embedded zero-tree wavelet algorithm (EZW). The watermark is embedded by replacing the significant wavelet coefficients of ECG signals by the corresponding significant wavelet coefficients of the host image. Aggeliki *et al.* [5] proposed a wavelet-based multiple watermarking scheme. In this scheme, four types of watermarks are embedded into the wavelet coefficients of medical images using a quantization of selected coefficients. Kallel *et al.* [6] developed an algorithm for embedding the patient's diagnosis in the spatial domain of medical image. A hash function is applied to 7 bit plane of image and XORed with the coded diagnosis inserted by the doctor. The resulting message is inserted in LSB plane. Huang *et al.* [7] implemented an algorithm which uses a part of patient's record in EXIF metadata as a watermark. The 8x8 blocks discrete cosine transform (DCT) is performed on the medical image and the middle frequency coefficients of each block are chosen to embed watermark bits. Most of previous research in literature has focused on preserving the resolution of the medical images after embedding the watermark regardless of testing the robustness of the schemes against different attacks.

Our research focuses on developing a watermarking algorithm to hide electronic patient record (EPR) in the medical image. The confidentiality of patient data is improved by hiding the EPR data as a watermark. In addition

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to that, both the storage and transmission bandwidth requirements for medical images are reduced.

The Digital Imaging and Communications in Medicine (DICOM) standard is the standard to exchange medical data. The DICOM medical image files are attached with header containing patient information which may be lost, attacked or disordered with other header file. However, the watermarking of medical images using patient information overcomes these problems [8]. However, there is a challenge that interleaving data in a medical image must not affect the image quality as this may result in wrong diagnosis.

In this paper, a new blind watermarking method is suggested. The medical image is transformed to two level wavelet packet transform. According to the energy of each band, we select two bands for watermarking to balance between robustness and impeccability. The watermark is the EPR which includes index information, patient information, diagnosis and some data related to the medical case. All the information is converted to binary form and coded by Error Correcting Code (ECC) to enhance robustness. A reference image selected as a binary logo of the medical center is used to embed the watermark. This paper is organized as follows; section 2 reviews the basic idea of DWPT. The proposed algorithm is described in Section 3. In section 4, the experimental results are introduced and discussed. Finally section 5 concludes the paper.

2. DISCRETE WAVELET PACKET TRANSFORM

The 2D- wavelet packet transform is a generalization of 2D- wavelet transform. It is a flexible tool offering richer image resolutions. In the orthogonal wavelet decomposition procedure, the generic step splits only the approximation coefficients sub-band of the image into four sub-bands. After this split, we obtain a sub-band of approximation coefficients (LL) and three sub-bands of detail coefficients (LH – HL – HH). The next step consists of splitting the new approximation coefficient sub-band in a recursive manner where the successive details sub-bands are never re-analyzed. In the corresponding wavelet packet situation, each detail coefficients sub-band is also decomposed into four sub-bands using the same approach as in approximation sub-band splitting. The DWPT for two levels is shown in Fig. (**1**).

The wavelet packet transform for an image gives a vast amount of sub-bands of wavelet coefficients at different resolutions. This allows more flexibility to select a sub-band or more to embed watermark and this will increase the watermarking security [9, 10].

LL_2LL_1	HL_2LL_1	LL_2HL_1	HL_2HL_1
LH_2LL_1	HH_2LL_1	LH_2HL_1	HH_2HL_1
LL_2LH_1	HL_2LH_1	LL_2HH_1	HL_2HH_1
LH_2LH_1	HH_2LH_1	LH_2HH_1	HH_2HH_1

Fig. (1). The DWPT for two levels.

3. PROPOSED METHOD

In this section, we present our proposed watermark embedding and extraction methods based on the DWPT.

3.1. Watermark Generation

As shown in Fig. (**2**), the patient information can be inserted in the electronic patient record (EPR) which includes personal information (name, age, ... etc.), clinic information (name, doctor name, ... etc.), diagnosis and some management information (record number, date, ... etc.). All the information is converted from ASCII code to binary code. After that, BCH error correcting code is used to encode the binary string. The resulting bitstream is the embedded watermark and using ECC enhances the robustness of the watermark.
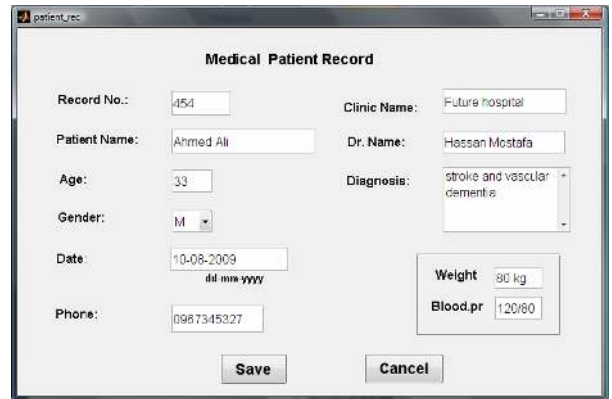

Fig. (2). Electronic patient record.

3.2. Watermark Embedding Method

The main steps for watermark embedding as shown in Fig. (**3**) are given below:

Step1

For a given NxN host medical image I, apply m-level DWPT which produces 4^m sub-bands of wavelet coefficients. Each sub-band is a matrix of coefficients at a specific resolution with size nxn where $n= N/4^{m/2}$.

Step 2

Compute the energy of each sub-band using the following equation:

$$E = \frac{1}{nxn}\sum_{i=1}^{n}\sum_{j=1}^{n} C^2(i,j)$$

(1)

where E denotes the energy, nxn is the size of sub-band, and C is the DWPT coefficient. To ensure trade-off between robustness and imperceptibility, two sub-bands $B1$ and $B2$ with middle energy are selected for watermark embedding. The $B1$ and $B2$ are divided into $4x4$ blocks $b_{r,k}$ where r is the sub-band number 1 or 2 and $k =1, ..., n/4$ is the block number.

Step 3

Prepare a greyscale reference image R whose size is equal to nxn (size of sub-band). The reference image is also divided into blocks R_k of $4x4$ pixels where $k=1,...,n/4$. This reference image is used for blind embedding.

Step 4

One bit of the watermark is embedded per block. Based on the value of the bit, the block of the reference image R_k is

added to the corresponding sub-band block $b_{r,k}$ according to the following rule:

$$b'_{r,k} = \begin{cases} b_{r,k} + \alpha R_k & if\ w = 0 \\ b_{r,k} - \alpha R_k & if\ w = 1 \end{cases} \qquad (2)$$

where α is the strength and w is the watermark bit. The number of blocks of *B1* plus *B2* equals the number of embedded watermark bits.

Step 5

The process in *step 4* is repeated up to the length of the watermark bitstream.

Step 6

Apply the inverse discrete wavelet packet transform to the modified wavelet coefficients to obtain the watermarked image *I'*.
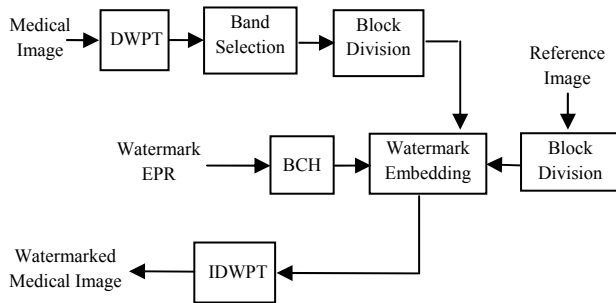

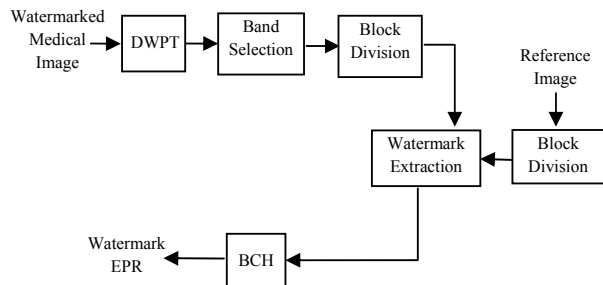**Fig. (3).** Watermark embedding algorithm.

Fig. (4). Watermark extraction algorithm.

3.3. Watermark Extraction Method

The extraction of patient information from the watermarked medical image is blind so we don't need the original medical image to extract patient information as shown in Fig. (**4**). The procedure is described in the following steps:

Step 1

For a given *NxN* watermarked (and may be attacked) medical image *I'*, apply *m*-level DWPT which produces 4^m sub-bands of wavelet coefficients.

Step 2

Choose the same two sub-bands with middle energy used in the watermark embedding and divide them into *4x4* blocks $b_{r,k}$

Step 3

Use the greyscale reference image *R* with size *nxn*. Divide the reference image into blocks R_k of 4x4 pixels where k=1,...,n/4.

Step 4

For each block, compute the correlation coefficient value ***corr*** between the reference image block and the corresponding block of watermarked sub-bands as shown in equation 3:

$$corr = \frac{1}{4x4} R_k \cdot b_{r,k} \qquad (3)$$

The recovered watermark bit is selected as follow:

$$w' = \begin{cases} 0 & if\ corr \geq 0 \\ 1 & if\ corr < 0 \end{cases} \qquad (4)$$

Step 5

Apply the steps of the watermark generation section in reverse order to obtain the patient information.

4. EXPERIMENTAL RESULTS

The performance of the proposed algorithm is tested on 8 greyscale medical images as shown in Fig. (**5**). Four types of medical images CT, MRI, and MRA and radiological of size 512× 512 pixels have been used. By applying two level DWPT, the size of each sub-band is 128x128 pixels. Two sub-bands are chosen to embed watermark and are divided into 4x4 blocks so the total number of blocks are 2*(128/4*128/4) = 2048 blocks.

The size of the patient information inserted into EPR is 136 characters which has been converted into binary matrix of 7x136 (each character represented by 7 bits). By using BCH code, the binary matrix becomes 15x136. The binary matrix has been converted into vector of 2040 bits. The bitstream is padded by zeros to become of length 2048. However, each watermark bit is embedded into one block. The reference image is chosen as a hospital logo of size 128x128.

(a) MRI1   (b) MRA1   (c) CT1   (d) Radio1

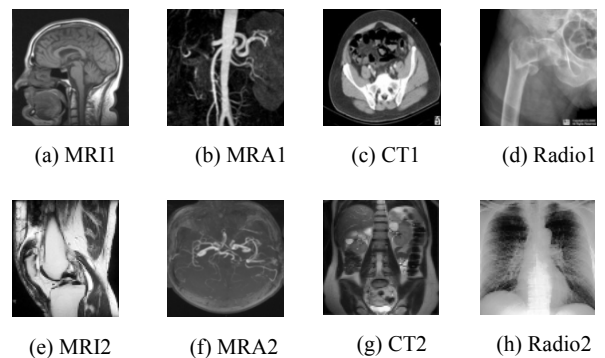(e) MRI2   (f) MRA2   (g) CT2   (h) Radio2

Fig. (5). Tested greyscale medical images [12].

The performance of the proposed watermarking approach is evaluated in terms of the imperceptibility and robustness against various attacks. The Peak-Signal-To-Noise Ratio (PSNR) is used to measure the visual quality of watermarked and attacked image [11] and is defined as:

$$PSNR = 10 \log \frac{255^2}{MSE} \qquad (5)$$

where MSE is the mean squared error between the original and distorted image and is defined as follows:

$$MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} [I(i,j) - I'(i,j)]^2 \qquad (6)$$

where *m, n* give the size of the image and $I(i,j), I'(i,j)$ are the pixel values at location *(i,j)* of the original and distorted images respectively. However, robustness is measured by the normalized correlation coefficient (**NC**) whose peak value is one and bit error rate (**BER**). The **NC** and BER are calculated according to the formulas (7) and (8) respectively:

$$NC = \frac{\sum_i \sum_j W(i,j) * W'(i,j)}{\sqrt{\sum_i \sum_j W(i,j)^2} \sqrt{\sum_i \sum_j W'(i,j)^2}} \qquad (7)$$

$$BER = \frac{1}{h*g} \sum_{i=1}^{h} \sum_{j=1}^{g} w(i,j) \oplus w'(i,j) \qquad (8)$$

where *h, g* are the width and height of the watermark *w*.

Fig. (**6**) shows an original image MRI2 and its watermarked version. The PSNR value between these two images is 39.0999 dB. As evidence from both images, there is no visual difference between the original and watermarked image which satisfy the strict requirements of medical image watermarking.
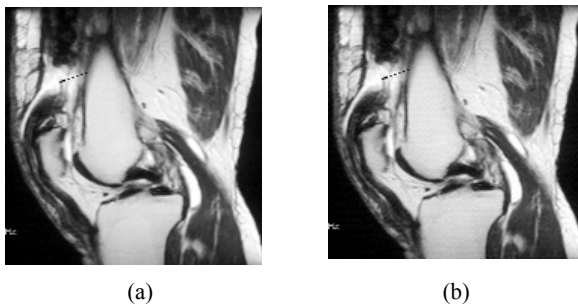

(a)   (b)

Fig. (6). (**a**) Original Image (**b**) Watermarked Image.

Table **1** shows the PSNR, NC and BER for all tested images in no attack case. The result shows that the watermark is retrieved successfully without any errors, the NC value is 1.000 and BER is 0.0 for all tested images.

The four types of medical images are subject to different attacks to measure the robustness of the watermarking algorithm. Tables **2** to **9**, show the PSNR, NC and BER for the case of attacked images. Analysis of the results shows that our proposed scheme has high degree of robustness to sharpen and automatic equalization attacks. The patient information can be recovered without any errors, BER = 0% and the similarity between recovered and original information is equal to 1 for the four types of images as shown in Tables **3** and **8**.

For Gaussian noise attack, the patient information is recovered with BER=0% and NC=1when the variance is

0.001. However, with variance of 0.005 the MRI1 and CT1images are recovered by 0.7%, and 0.3% BER as shown in Table **2**. For median filter attack as indicated in Table **4**, the radiological image type resulted in the best robustness with BER=0% and NC=1while the other three types have watermark recovery errors.

Table 1.   Performance of Medical Image Watermarking (no Attack)

Image	PSNR	NC	BER
MRI1	39.0999	1	0
MRI2	39.2094	1	0
MRA1	39.3009	1	0
MRA2	39.1004	1	0
CT1	39.9446	1	0
CT2	39.0999	1	0
Radio1	39.2623	1	0
Radio2	39.1017	1	0

Table 2.   Gaussian Noise Attack

Image	Variance = .001			Variance = .005		
	PSNR	NC	BER	PSNR	NC	BER
MRI1	29.5426	1	0	23.1001	0.9919	0.0074
MRI2	33.3226	1	0	27.4583	1	0
MRA1	33.1387	1	0	26.7269	1	0
MRA2	32.9575	1	0	27.5835	1	0
CT1	32.8834	1	0	27.2033	0.9963	0.0032
CT2	33.4091	1	0	27.2776	1	0
Radio1	33.5368	1	0	27.8753	1	0
Radio2	34.2908	1	0	27.9641	1	0

Table **5** illustrates the results of image attack at different values of the Gamma correction parameter (Par). The watermark can be recovered with no BER for value 2 while for value 0.5, both CT1 and Radio1 images are recovered with 7% and 0.1% respectively. On the other side, the patient information is correctly recovered without any error in the case of contrast attack by factor 10. But, when this factor is increased to 30 the patient information failed to be extracted from the image without error except for the case of the MRI1 and Radio2 images as indicated by Table **6**.

In Table **7** the medical image is rotated by 5°. Before extracting the watermark, the image is re-rotated to its original position. The results indicate that the patient information can be extracted with BER = 0% and NC=1 except for the MRI1, CT1 and CT2 images where BER= 0.2%, 0.4%, and 0.1%, and NC=0.9977, 0.9951, and 0.9988 consequently. Finally, Table **9** shows the robustness of our

watermarking scheme against JPEG attacks with different quality factors (QF). For QF = 90%, 80%, the BER =0% and NC=1 for the four types of medical images so the watermark is successfully recovered but for QF = 70%, and 60% the watermark is recovered with BER for some types of images.

Table 3. **Sharpen Attack**

Image	Par =.2			Par =.6		
	PSNR	NC	BER	PSNR	NC	BER
MRI1	24.4399	1	0	25.1128	1	0
MRI2	26.2089	1	0	27.0520	1	0
MRA1	27.0071	1	0	27.8567	1	0
MRA2	24.9004	1	0	25.6724	1	0
CT1	23.6153	1	0	24.3030	1	0
CT2	26.1926	1	0	26.9339	1	0
Radio1	24.1933	1	0	25.1200	1	0
Radio2	24.7326	1	0	25.4788	1	0

Table 4. **Median Filter Attack**

Image	3x3		
	PSNR	NC	BER
MRI1	36.1538	0.9736	0.0242
MRI2	37.3962	0.9645	0.0305
MRA1	41.1811	0.9902	0.0084
MRA2	37.7166	0.9915	0.0074
CT1	33.0626	0.9439	0.0483
CT2	27.5777	0.9842	0.0137
Radio1	32.3532	1	0
Radio2	32.7215	1	0

Table 5. **Gamma Correction Attack**

Image	Par =.5			Par = 2		
	PSNR	NC	BER	PSNR	NC	BER
MRI1	14.5060	1	0	13.0705	1	0
MRI2	15.6436	1	0	15.1122	1	0
MRA1	17.6259	1	0	14.2096	1	0
MRA2	14.1319	1	0	12.5231	1	0
CT1	16.0795	0.9150	0.0714	15.1780	1	0
CT2	15.7198	1	0	13.1466	1	0
Radio1	13.4521	0.9988	0.0011	14.3092	1	0
Radio2	13.6493	1	0	14.7227	1	0

Table 6. **Contrast Attack**

Image	Factor =10			Factor =30		
	PSNR	NC	BER	PSNR	NC	BER
MRI1	31.474	1	0	22.471	1	0
MRI2	31.454	1	0	22.347	0.982	0.016
MRA1	30.586	1	0	22.308	0.979	0.018
MRA2	31.814	1	0	23.343	0.995	0.004
CT1	34.351	1	0	25.079	0.888	0.092
CT2	30.787	1	0	22.286	0.996	0.003
Radio1	34.449	1	0	25.680	0.995	0.004
Radio2	33.120	1	0	24.524	1	0

Table 7. **Rotate Attack**

Image	Rotation ($5^o \rightarrow -5^o$)		
	PSNR	NC	BER
MRI1	29.8776	0.9977	0.0021
MRI2	23.3739	1	0
MRA1	32.2934	1	0
MRA2	30.5850	1	0
CT1	28.0750	0.9951	0.0042
CT2	21.5120	0.9988	0.0011
Radio1	21.2127	1	0
Radio2	18.0939	1	0

Table 8. **Automatic Equalization Attack**

Image	PSNR	NC	BER
MRI1	13.0778	1	0
MRI2	26.5190	1	0
MRA1	10.1132	1	0
MRA2	10.7452	1	0
CT1	18.1084	1	0
CT2	10.2840	1	0
Radio1	19.4670	1	0
Radio2	20.2793	1	0

5. CONCLUSIONS

In this paper, a new blind watermarking scheme has been introduced and developed to embed patient information in a private and secure manner. The proposed scheme satisfies the security of medical patient information and allows

Table 9.   JPEG Compression Attack

Image	QF=90%			QF=80%			QF=70%			QF=60%		
	PSNR	NC	BER	PSNR	NC	BER	PSNR	NC	BER	PSNR	NC	BER
MRI1	39.1283	1	0	39.1954	1	0	38.7686	1	0	39.2142	0.9606	0.0357
MRI2	38.7412	1	0	38.6044	1	0	37.8652	1	0	38.4243	0.9890	0.0095
MRA1	39.3926	1	0	39.4710	1	0	39.3432	1	0	40.4580	0.8575	0.1229
MRA2	38.3999	1	0	38.0280	1	0	37.3049	1	0	37.2851	1	0
CT1	38.8473	1	0	37.8439	1	0	36.9995	0.9667	0.0284	36.0498	0.9590	0.0347
CT2	38.9885	1	0	38.9252	1	0	38.0778	1	0	39.2624	0.9939	0.0053
Radio1	37.6862	1	0	37.2173	1	0	36.5652	1	0	36.1547	1	0
Radio2	38.2032	1	0	38.0067	1	0	37.3545	1	0	37.4947	1	0

sharing the medical information remotely and manageably without extra cost or storage space and without any effect on medical image quality. We examined the security of the scheme by applying some attacks and measuring the robustness of the scheme by BER and NC and examining the visual quality of medical image by PSNR.

Experimental results show that the proposed scheme is robust against common attacks such as Gaussian noise, gamma correction, automatic equalization, contrast adjustment, rotation, and sharpening, median filter and JPEG compression with different QF. Also it has been noticed that the Radiological image is the most robust type of medical image against attacks. Although the scheme resists most attacks, there is some none satisfactory performance in the area of median filtering and contrast adjustment by factor 30.

In the future research, we will try to enhance our algorithm in order to obtain watermarked medical images with less degradation and to have recovered watermark with better accuracy.

ACKNOWLEDGEMENT

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