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Blind Medical Image Watermarking for Secure Telemedicine Applications using IWT-SVD

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Abstract : In this paper we present a new region based blind medical image watermarking (MIW) scheme using integer wavelet transform (IWT) and singular value decomposition (SVD). In the proposed scheme feature of region of interest (ROI) is generate using IWT coefficients and embedded in region of no interest (RONI) as ROI recovery information. ROI is watermarked for tamper detection in the spatial domain. In ROI authentication and parity bit is calculated for each block on the basis of average intensity of 4 × 4 block and its 2 × 2 sub blocks and stored in the mapped block. Electronic health record (EHR) and hospitals logo is embedded as a robust watermark in RONI using IWT-SVD hybrid transform for providing confidentiality and authenticity. Various computer simulations were conducted to evaluate the performance of the proposed scheme. Simulation results show that the proposed scheme achieves not only good imperceptibility but also good robustness against intentional/unintentional attacks. We have compared our proposed scheme with popular MIW scheme. Our scheme shows comparatively better results in terms of imperceptibility and robustness.

Keywords : IWT, SVD, ROI, RONI, PSNR

1. INTRODUCTION

Widespread development in computer communication and digital technology has facilitated growth of telemedicine where digital medical images and patient's EHR are transmitted over networks for clinical interpretation and diagnosis [1]. But, such transmission of the images through open network is raising ethical issues, like image retention, privacy, integrity, malpractice liability, etc. For efficient telemedicine applications three requirements: confidentiality, authenticity, and integrity must be simultaneously satisfied [3]. Confidentiality ensures that only intended users can access the transmitted image. By integrity we mean that the image is not tampered. Authenticity confirms the origin of the image and ensures that the image belongs to the claimed patient. In present scenario cryptography and digital image watermarking are the two major methodologies used to meet these requirements [4]. Cryptography-based approach has a major limitation that once the medical image is deciphered, or the digital signature is removed, then its integrity and authenticity cannot be verified. Therefore, digital image watermarking is the most promising technology for securing digital intellectual property and information [5]. Digital image watermarking can provide confidentiality, ownership/origin authentication, and ensure integrity in transmitted medial images. Confidentiality can be provided by interleaving patient's EHR into the related medical image as robust watermark. In the same way, authenticity can be ensured by embedding the physician's or the hospital's logo as a robust watermark in the image. Fragile or cryptographic hash watermark is used to verify the integrity. Digital image watermarking is defined as process of embedding watermark into the host/cover image [6].

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In the past few decades many medical image watermarking (MIW) techniques have been proposed in the literature. These techniques can be classified into: non-reversible, reversible and region based methods. In region based MIW methods medical image is divided into region of Interest (ROI) containing the region used for diagnosis and the region of non-interest (RONI) containing non-substantial clinical findings [7]. ROI/RONI is usually selected manually by doctors and radiologists using computer selection tool. Some of the region-based MIW techniques are discussed here. Al-Qershi and Khoo [8] presented a scheme in which tamper is localized by comparing the average pixel value of each ROI block with the extracted average pixel value from the watermark. Guo and Zhuang [9] came up with a watermarking scheme for tamper localization based on difference expansion using the concept of ROI shading. Memon et al. [10] suggested a blind hybrid watermarking scheme. This scheme has good imperceptibility, but it is not robust against attacks. Acharya et al. [11] suggested embedding patient information by replacing LSB plane, and using error correction techniques for reliable storage and transmission of medical images over noisy channel. Guo et al.[12] have presented a lossless region based MIW scheme for improved authentication and security based on difference expansion of adjacent pixel values. Arsalan et al.[13] proposed a hybrid reversible watermarking method using IWT and genetic algorithm GA for medical and millitary imagery. Anushudha et al. [14] suggested hybrid MIW schem based on DNA encryption and GA. This scheme has high security and capacity. Thabit and khoo [15] proposed another region based MIW scheme based on Slantlet transform (SLT) and IWT for tamper detection, localization, and recovery. Extracted feature of ROI and EPR is embedded as robust watermark in RONI. This scheme is robust against unintentional attacks, and ROI is recovered with good perceptual quality. We are motivated by the ROI recovery technique proposed in [15].

Remaining paper is organized as follows: the proposed MIW scheme is described in detail in section 2. Experimental results and discussion is presented in section 3. Concluding discussion is given section 4.

2. THE PROPOSED SCHEME

In the proposed scheme a medical image is divided into ROI and RONI. ROI is a polygon selected manually by radiologist or physician. ROI is watermarking in spatial domain for tamper detection. Feature of ROI is extracted using IWT and embedded in RONI by modifying horizontal and vertical coefficients of IWT sub bands. EHR and binary hospital logo is embedded in RONI by exploiting the relationship of U and V components of SVD. Proposed scheme has six subsections dealing with ROI feature extraction, ROI recovery, RONI embedding, RONI extraction, ROI embedding and ROI tamper detection.

2.1. ROI Feature Extraction

ROI features are extracted using the following steps :

Step 1 : Apply 1-level IWT on ROI blocks. Four sub bands *i.e.* CA, CH, CV and CD are obtained.

Step 2 : Select CA sub-band for feature generation. CA coefficients are adjusted to range from 0 to 55 for 8-bit representation using Eq.1:

$$\mathrm{CA}_{\mathrm{new}}(i,j) = \begin{cases} 0 & \text{if } \mathrm{CA}\,(i,\ j) < 0 \\ 255 & \text{if } \mathrm{CA}\,(i,\ j) \geq 255 \\ \mathrm{CA}(i,\ j) & \text{if } 0 \leq \mathrm{CA}\,(i,\ j) \leq 255 \end{cases} \tag{1}$$

where CA is the original approximation coefficients, $\mathrm{CA}_{\mathrm{new}}$ is the adjusted CA coefficients, and *i, j* are the coefficient coordinates.

Step 3 : Reshape the $\mathrm{CA}_{\mathrm{new}}$ coefficients matrix into a 1-D row vector $\mathrm{CA}_{\mathrm{row}}$.

Step 4 : Convert $\mathrm{CA}_{\mathrm{row}}$ coefficients into 8-bit binary number and save them in a row vector R.

2.2. Image recovery from the extracted features

Image can be recovered from its features using following steps:

Step 1: Convert R from binary to decimal and reshape the row of coefficients to obtain $\mathrm{CA}_{\mathrm{new}}$ matrix.

Step 2: Initialize CV, CH and CD coefficients as zero.

Step 3: Apply inverse IWT on CA_{new}, CH, CV and CD to obtain the recovered image I_R.

2.3. Embedding in RONI

Watermarks *i.e.* ROI features, hospital logo and EHR are embedded in 16 × 16 RONI block as follows:

Step 1: Apply IWT on the block to get four sub bands CA, CH, CV and CD of size 8 × 8.

Step 2: Watermark bits $b(i)$ of row vector R is embedded by changing $CH(x, y)$ and $CV(x, y)$ using Eq.2 and Eq.3:

$$\text{if } b(i) = 1 \text{ and } D1 = CH(x, y) - CV(x, y) < T \begin{cases} CH'(x, y) = CH(x, y) + \dfrac{(T - D1)}{2} \\ CV'(x, y) = CV(x, y) - \dfrac{(T - D1)}{2} \end{cases} \tag{2}$$

Else if $D1 = CH(x, y) - CV(x, y) \geq T$, no change.

Where T is a threshold to control watermark invisibility

$$\text{if } b(i) = 0 \text{ and } D2 = CV(x, y) - CH(x, y) < T \begin{cases} CH'(x, y) = CH(x, y) - \dfrac{(T - D2)}{2} \\ CV'(x, y) = CV(x, y) + \dfrac{(T - D2)}{2} \end{cases} \tag{3}$$

Else if $D2 = CV(x, y) - CH(x, y) \geq T$, no change.

This process is repeated for embedding in all 64 block coefficients.

Step 3: EHR text is converted to binary and the resultant bit stream is encoded using BCH (15,11,1) for more robustness and saved as 'EHR_{bin}'. Concatenate 'EHR_{bin}' with the binary watermark of hospital logo as 'W_{bin}'.

Step 4: Divide CD sub bands in 4×4 sub-blocks and apply SVD.

$$CD = U \times S \times V^T \tag{4}$$

Step 5 : One watermark bit is embedded in each block by changing the relation between the second and the third elements in the first column of U matrix *i.e.* $U_{2,1}$, $U_{3,1}$ using Eq.5 and Eq.6:

$$\text{if } W = 1 \text{ and } U_{2,1} - U_{3,1} < -T \begin{cases} U_{2,1} = U_{2,1} \times (U_{avg} + T/2) \\ U_{3,1} = U_{3,1} \times (U_{avg} - T/2) \end{cases} \tag{5}$$

Else, do nothing.

$$\text{if } W = 0 \text{ and } U_{2,1} - U_{3,1} < T \begin{cases} U_{2,1} = U_{2,1} \times (U_{avg} - T/2) \\ U_{3,1} = U_{3,1} \times (U_{avg} + T/2) \end{cases} \tag{6}$$

Else, do nothing.

where $U_{avg} = (|U_{2,1}| + |U_{3,1}|)/2$. $|A|$ is the absolute value of A. This process is repeated to embed all bits.

Step 6 : Apply inverse SVD on all 4 × 4 CD sub-blocks to CD'.

Step 7: Apply inverse IWT on CA, CV', CH' and CD' frequency coefficients to obtain the watermarked image I_w.

2.4. Extraction from the RONI

Step1 : Separate RONI of I_w and divide it into 16 × 16 sub blocks. Apply IWT on the block to get CA', CH', CV' and CD'

Step 2 : Extract the watermark bits b'(i) from CH′ (x, y) and CV′ (x, y) using following Eq:

$$b'(i) = \begin{cases} 1, & \text{if } CD'(x, y) \geq CV'(x, y) \\ 0, & \text{if } CV'(x, y) > CH'(x, y) \end{cases} \quad (7)$$

Step 3 : Divide CD' sub bands in 4×4 blocks and apply SVD on each block.

$$CD' = U' \times S' \times V'^{T} \quad (8)$$

Step 4 : The relation between $U'_{2,1}$, $U'_{3,1}$ of the U' matrix is used to extract the first watermark bit $w1$, as shown in Eq.9.

$$w1 = \begin{cases} 0, & \text{if } U'_{2,1} > U'_{3,1} \\ 1, & \text{if } U'_{2,1} \leq U'_{3,1} \end{cases} \quad (9)$$

Repeat this for all the sub blocks

Step 5 : Cascade and reshape watermark bits extracted to reconstruct the three watermarks *i.e*. Extracted feature (CA_f), EHR and hospital logo.

Step 6 : Perform BCH decoding on extracted EHR watermark bits to get the extracted EHR text watermark.

2.5. Embedding in ROI

Step 1 : ROI is divided into 4×4 non-overlapping blocks. And further divide these blocks into 4 sub-blocks of size 2 × 2.

Step 2 : ROI feature is generated using proposed algorithm in section 1.1. The binary sequence of extracted features is saved as R.

Step 3 : For each block calculate average intensity (B_{avg}) and average intensity of its sub block (S_{avg}). Calculate the authentication bit (v) and parity bit (p) for each sub blocks using following equations.

$$v = \begin{cases} 0, & \text{if } B_{avg} > S_{avg} \\ 1, & \text{else} \end{cases} \quad (10)$$

$$p = \begin{cases} 0, & \text{if } S_{avg} \text{ is odd} \\ 1, & \text{else} \end{cases} \quad (11)$$

Step 4 : One to one ROI block mapping is done using mapping technique given by following Eq.

$$\vec{B} = [(K \times B) \bmod M] + 1 \quad (12)$$

Where, B is ROI block number assigned in raster scan order. $B \in (1, 2, 3, \ldots, M)$. M is the total number of ROI blocks. K is the largest prime number between 0 to M. The watermark in ROI will be embedded in sequence $X \rightarrow Y \rightarrow Z \rightarrow \ldots \rightarrow X$, which implies that authentication bit (v) and parity bit (p) of block X will be embedded in first row of block Y using LSB replacement, and that of block Y into block Z, and so on.

2.6. Extraction from ROI

Authentication and parity bits are calculated and compared with extracted one to detect tampered ROI block.

Step 1: Perform one to one block mapping using Eq.12 and extract v and p bits of each sub block from mapped block.

Step 2: Calculate v' and p' for each sub blocks using Eq.10 and Eq. 11.

Step 3: Compare extracted (v, p) with (v', p') respectively. If they are not equal then the block are marked as tampered otherwise not tampered.

Step 4: For tampered blocks obtain the extracted feature of ROI from RONI and recover the block using algorithm discussed in section 2.2.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Various computer simulations were carried out for performance evaluation of the proposed scheme in terms of imperceptibility, robustness, tamper detection, localization and recovery using MATLAB R2013a on gray scale medical images of size 512 × 512 of different modalities *i.e*. X-ray, CT scan, mammogram and ultrasound and watermarks *i.e*. binary image of hospital logo having size 32 × 32 and EHR text data as shown in figure 1. We have used weight factor or threshold 'T' value as 0.05 in all cases.

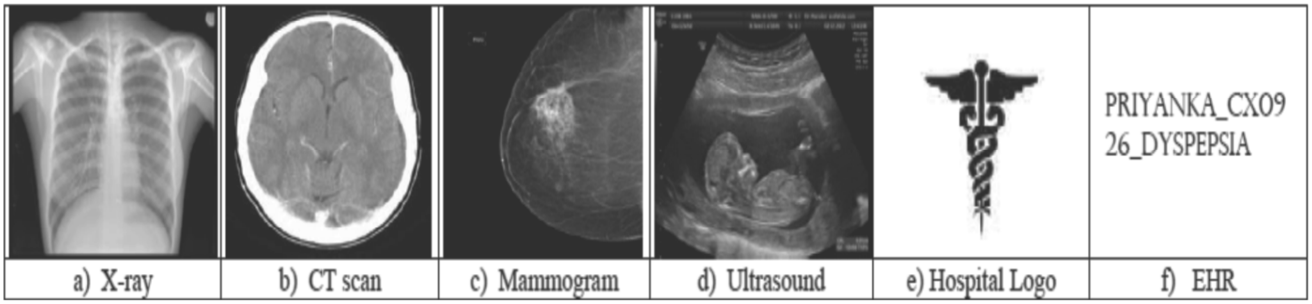

Fig. 1. Medical test images and watermarks: (*a*) X-ray, (*b*) CT scan, (*c*) Mammogram, (*d*) Ultrasound, (*e*) Hospital Logo, (*f*) EHR

3.1. Perceptual quality analysis

For perceptual analysis PSNR is calculated between original and watermarked images to validate the imperceptibility performance of proposed scheme. Watermarked images and their corresponding PSNR value is given in figure 2. An average PSNR is around 43 dB which shows that proposed scheme is highly imperceptible. Thus, the watermarked images can retain the diagnostically significant information even after watermark contents are embedded into it.

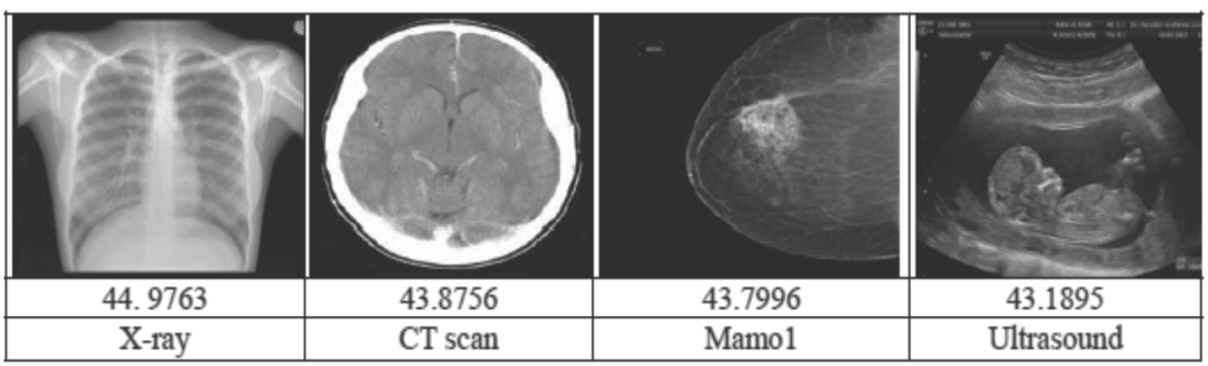

Fig. 2. Watermarked medical images and corresponding PSNR(dB) values.

3.2. Robustness analysis

Watermarked images may suffer from a variety of attacks like salt & pepper noise, histogram equalization, Gaussian noise, JPEG compression, etc. Watermark is extracted from watermarked image which may have undergone attack(*s*). Robustness against such attacks is evaluated using normalized correlation coefficient (NCC) and bit error rate (BER). Values obtained for these parameters in the presence of different attacks are given below in Table 1.

Table 1. NCC and BER values of extracted hospital logo and EHR under different attacks

Attack	*Medical image* / *Watermark*		*X-ray*	*CT Scan*	*Mammogram*	*Ultrasound*
Salt & pepper (0.0011)	Hospital Logo	BER	0.0016	0.0020	0	0.0014
		NCC	0.9935	0.9950	0.9939	0.9961
	EHR	BER	0	0.0034	0	0.0002
Histogram equalization	Hospital Logo	BER	0.0020	0.0391	0.0254	0.0092
		NCC	0.9550	0.9777	0.9374	0.9681
	EHR	BER	0	0.0010	0	0.0006
Gaussian noise attack (0.0001).	Hospital Logo	BER	0.0156	0.0026	0.0085	0.0109
		NCC	0.9613	0.9950	0.9851	0.9930
	EHR	BER	0.0015	0.0155	0.0008	0.0064
Average filtering	Hospital Logo	BER	0.0049	0.0107	0	0.0026
		NCC	0.9876	0.9828	1	0.0064
	EHR	BER	0.0017	0.0499	0	0.0150
JPEG (QF = 90)	Hospital Logo	BER	0.0009	0.0020	0	0.0020
		NCC	0.9975	0.9950	1	0.9950
	EHR	BER	0	0.0155	0	0.0088
JPEG (QF = 20)	Hospital Logo	BER	0.0088	0.0342	0.0303	0.0120
		NCC	0.9779	0.9751	0.9230	0.9759
	EHR	BER	0.0029	0.1635	0.1962	0.0183

3.3. Tamper Detection, Localization and Recovery

We have imposed erasing and copy & paste tampering processes on the watermarked image to evaluate the tamper detection and recovery process of the proposed scheme. The proposed scheme can successfully detect and recover the tampered ROI area with good visual quality as shown in figure 3.

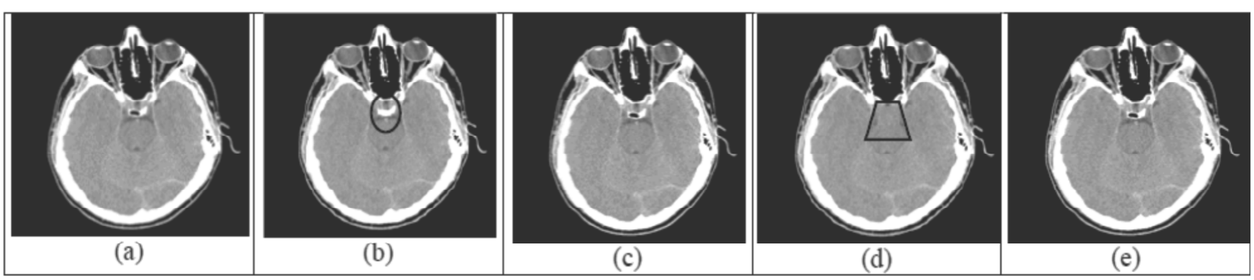

Fig. 3. Tamper localization and recovery. (*a*) Watermarked image, (*b*) Tamper localization of erasing, (*c*) Recovery of erasing tampering, (*d*) Tamper localization of copy & paste, (*e*) Recovery of copy & paste tampering

3.4. Comparative Analysis

In this sub section the performance of the proposed method is investigated by comparing the experimental results with Parah et al.[7] scheme. The average PSNR of [7] is about 41 dB whereas in our scheme average it is more than 43dB, so our proposed scheme is better in terms of imperceptibility. We have compared robustness using CT scan image. From the comparison shown in Table 2 we can observe that in most of the attacks our proposed scheme is comparatively more robust than scheme proposed in [7]. From figure 4 we can see that NCC values of extracted watermark is more than [7]. So, we can conclude that our method surpasses Parah et. al.[7] scheme in terms of imperceptibility and robustness.

Table 2. BER and NCC of extracted watermarks of proposed scheme and Parah et. al. scheme [7] under various attacks

Attack	*Hospital Logo*				*EHR*			
	Proposed Scheme		*Parah et al.[7] scheme*		*Proposed Scheme*		*Parah et al.[7] scheme*	
	BER	NCC	BER	NCC	BER	NCC	BER	NCC
Salt & pepper (0.0001)	0.0020	0.9950	0.0500	0.9864	0.0034	0.9931	0.0093	0.9918
Histogram Equalization	0.0391	0.9777	0.9800	0.9901	0.0310	0.9388	0.0215	0.9767
Gaussian Noise	0.0020	0.9950	0.0742	0.9265	0.0155	0.9691	0.0509	0.9506
Average Filtering	0.0107	0.9828	0.2949	0.9652	0.0499	0.9006	0.1243	0.8926
Sharpening	0.0049	0.9876	0	1	0.0034	0.9931	0	1
JPEG(QF = 50)	0.0088	0.9874	0.1035	0.9737	0.0120	0.9759	0.2202	0.9396

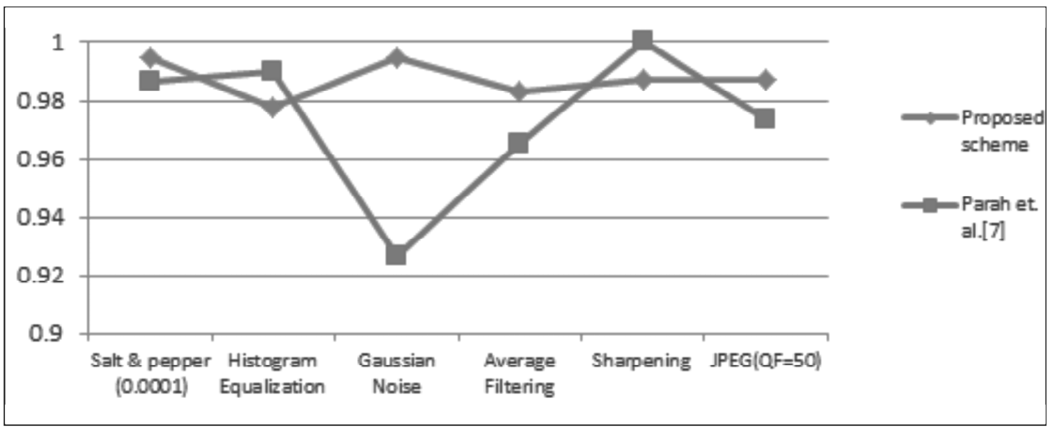

Fig. 4. Comparison of NCC of extracted watermark by the proposed scheme and Parah et. al. scheme[7]

4. CONCLUSION

In this paper, a blind region based medical image watermarking scheme is proposed for embedding dual watermark contents. IWT-SVD transform is used for enhanced imperceptibility and robustness. EHR, hospital logo and ROI feature has been embedded as watermarks confidentiality, authenticity and integrity respectively. The performance of proposed scheme is tested on medical images of different modalities. BCH encoding is used as for sensitive EPR data for its accurate retrieval. Average PSNR value is more than 43 dB for all types of watermarked medical images. Minimum NCC value is 0.9230 which is more than threshold. Moreover, the scheme is more robust than existing scheme under most types of common image processing attacks. Smaller size of ROI block enables to locate tampered region with more accuracy. Accuracy of tamper detection is more than 90% and recovery the recovered ROI has good visual quality.

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