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Secure Hybrid Robust Watermarking Technique for Medical Images

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Abstract

The protection of data is of at prime urgency in the medical field to boost the telemedicine applications. There is a need of robust and secure mechanism to transfer the medical images over the Internet. The proposed watermarking method is based on two popular transform domain techniques, discrete wavelet transforms (DWT) and discrete cosine transform (DCT). In the embedding process, the cover medical image is divided into two separate parts, region of interest (ROI) and non region of interest (NROI). For the identity authentication purpose, multiple watermarks in the form of image and text are embedding into ROI and NROI part of the same cover media object respectively. In order to enhance the security of the text watermark, Rivest-Shamir-Adleman (RSA) encryption technique is applied to the text watermark before embedding and the encrypted EPR data is embedded into the NROI portion of the cover medical image. The performance of the proposed method is evaluated for signal processing attacks and the desired outcome is obtained without significant degradation in extracted watermark and perceptual quality of the watermarked image.

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Keywords: *DWT, DCT, medical image, image and text watermarks, RSA, ROI and NROI*

1. Introduction

With the development of advanced technologies in computer networks and communication field, the transmission of medical information among medical institutions has become more prominent nowadays[1-4.] However, the technological advancements has eased the duplication, manipulation and unauthorized distribution of the medical

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data [5-7], resulting in the prerequisite for protection from unauthorized access and maintaining the integrity of medical data[8]. In the telemedicine, tele-diagnosis and tele-consultancy services, medical images play a prominent role for instant diagnosis, understanding of crucial diseases as well as to avoid the misdiagnosis[9]. For intellectual achievement and confidentiality, the copyright protection and content authentication of medical data is critical, while exchanging the information over open network[10-13]. The digital imaging and communication in medicine (DICOM) provides the basic mechanism to exchange the EPR data via open channel[14-15]. However, a header attached with DICOM images may be attacked or lost, resulting in the insecure transmission [16-17]. The confederation of digital watermarking and cryptography is the best proposal for protecting the medical data against misuse and illegal distribution[18-19]. The digital watermarking is a substantial way for ownership proof, content protection and authentication of medical data[20]. The main challenge for a good watermarking method is robustness and security of the hidden watermark against the surviving attacks[21-22]. Recently, higher robustness of watermarking schemes is achieved by discrete wavelet transform (DWT) [20-21, 23-29].

In this paper, a digital image watermarking method based on DWT and DCT is proposed. For the identity authentication purpose, multiple watermarks in the form of image and text are embedding into ROI and NROI part of the cover medical image. The DCT information of the watermark image contains low frequency information and as long as such information is not lost or lost a little, the watermarking image can be extracted well. To enhance the security of the confidential patient information, the EPR data is encrypted using public key cryptographic (RSA) techniques[30] before embedding in the cover medical image.

2. Proposed Method

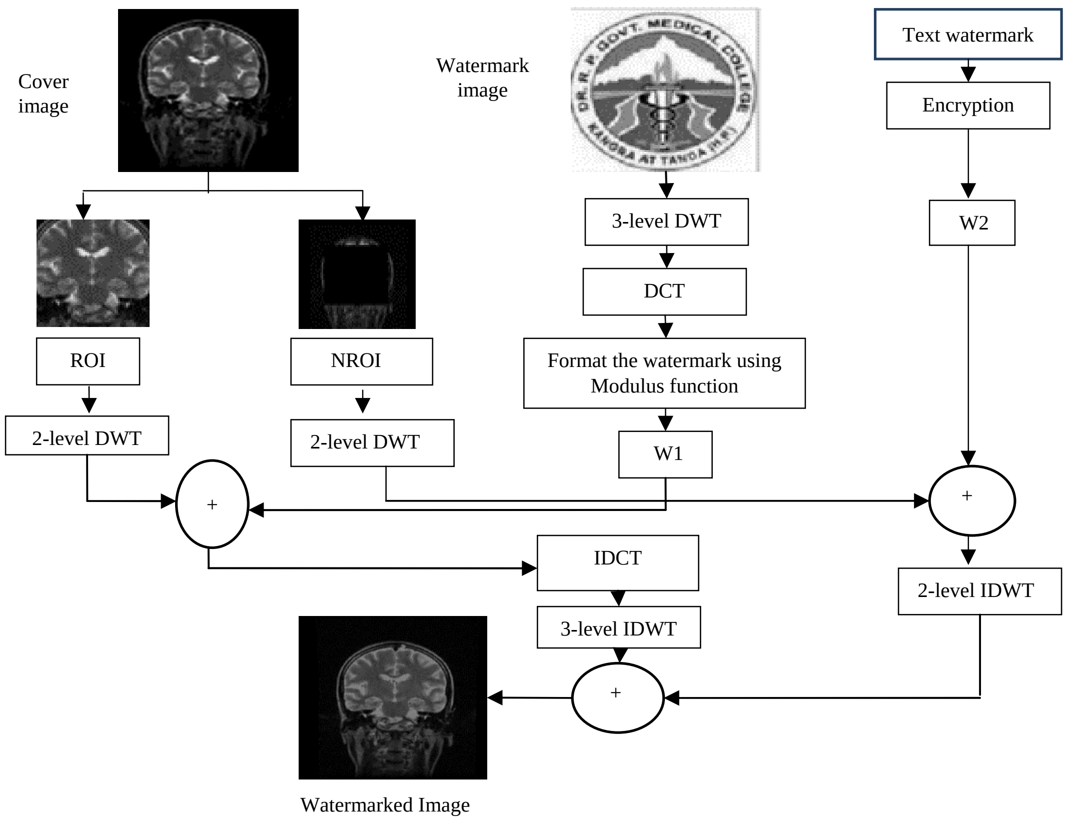
The proposed DWT-DCT based watermarking method increases the robustness and security of the watermarks without significant degradation of cover image quality against the signal processing attacks. Figure 1 (a) and Figure 1(b) illustrates the multiple watermark embedding and extraction process respectively. The algorithmic steps are discussed below:

2.1. Embedding Process

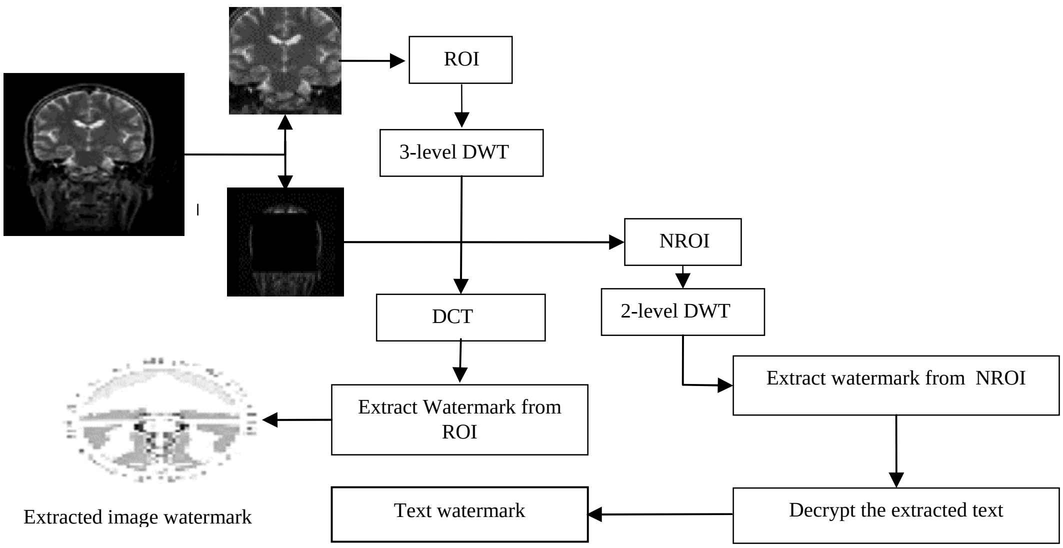
i. Segment the cover image into ROI and NROI parts. Apply second-level DWT on ROI and NROI of the cover image to obtain the sub-bands as LL2, LH2, HL2 and HH2.
ii. Apply third-level DWT on the watermark image and DCT transformation to LL3 sub-band of the DWT watermark image. Format the DCT transform of watermark image using modulus function to obtain watermark 'W1'.
iii. Select the electronic patient record (EPR) data file as text watermark and encrypt the watermark using public key cryptography to obtain the watermark 'W2'.
iv. Apply inverse discrete cosine transform (IDCT) and second-level inverse discrete wavelets transform (IDWT) to embed the image watermark in the ROI part of the cover image. Apply second-level inverse discrete wavelet transform (IDWT) to the embed text watermark in the NROI region.
v. Merge the embedded ROI and NROI parts of the medical cover image to form the final watermarked image.

2.2. Extraction Process

i. Segment the watermarked image into the ROI and NROI parts.
ii. Apply second-level DWT on NROI and third-level DWT on ROI of the cover medical image and DCT transform to the LL3 sub-band of ROI part of the cover.
iii. Extract the watermark 'W1' from the ROI part and encrypted text watermark 'W2'from NROI of the cover image respectively.
iv. Decrypt the watermark 'W2' using the public key cryptography to obtain EPR data.



(a)



(b)

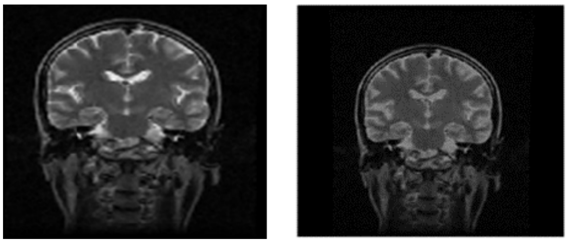
Fig. 1. (a) Watermark embedding process; (b) Watermark extraction process.

3. Experimental Results and Analysis

The watermarking embedding and extraction is done for the MRI, CT and Ultrasound images[31]. The medical image size 512×512 is used as the cover image, which is divided into the ROI and NROI regions. The watermark image is embedded to the ROI region and the encrypted EPR data consisting of 33 characters is embedded into the NROI region of the cover image. Figure 2 (a) and Figure 2 (b) shows the original and watermarked image respectively. Figure 3 (a) and Figure 3 (b) shows the health center logo as image and EPR data as text watermark respectively. The quality of the watermarked image is evaluated by the parameter peak signal to noise ratio (PSNR) and the robustness of the extracted image and text watermark is evaluated by the parameter normalize cross correlation (NC) and bit error rate (BER) respectively. We simulated the proposed method using MATLAB. Based on the experimental results, the NC, BER and PSNR values are illustrated in Table 1 to 2.

Table 1 describes the NC and BER values for watermark w1 and w2 respectively at different gain factors ranging from 0.01 to 1. It is observed that the robustness performance is increasing with increasing the gain factors. In this Table, the NC value evaluated at different gain factors and it is observed that the maximum value is obtained at gain factor = 1 for MRI images. Table 2 shows the PSNR performance obtained by the proposed method without the signal processing attacks. From the experimental result it is observed that the PSNR value decreases with the increase in gain factor.

Table 3 shows the NC and BER values for w1 and w2 respectively for different noise attacks at different levels. Referring this table it is observed that the proposed method is robust against the different noise attacks at various noise levels. Table 4 shows the NC and BER performance of the proposed method has been evaluated for different signal processing attacks. It is observed from the NC value for an MRI image is much better than CT scan images. To protect the confidential EPR data, it is encrypted using the public key cryptographic algorithms such as RSA.



(a) (b)

Fig. 2. (a) Cover image; (b) Watermarked image.

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(a) (b)

Fig. 3. (a) Image watermark; (b) Text watermark.

At different value of prime numbers P and Q, the encryption and decryption time for different EPR text files is evaluated. Table 5 shows the encryption and decryption time for different EPR text files is as at different P and Q values. The EPR data is encrypted by using the public key cryptographic method. Due to the limited resource capacity of our experimental setup, we simulated the proposed algorithm on smaller prime numbers. But it can also perform well with large prime numbers. The encryption and decryption time depends on the size of the EPR data file.

Table 1. NC and BER values of the proposed method at different gain factor.

Images		NC				BER(in %)			
		Gain Factor (K)				Gain Factor(K)			
		0.02	0.05	0.8	1	0.02	0.05	0.8	1
MRI	Brain	0.9314	0.9867	0.9999	1.0000	0	0	0	0
	Spine	0.9323	0.9876	0.9999	1.0000	0	0	0	0
CT	Brain	0.9314	0.9867	0.9999	1.0000	0	0	0	0
	Heart	0.9214	0.9767	0.9988	1.0000	0	0	0	0

Table 2. PSNR values at different gain factors.

Images		PSNR(dB)			
		Gain Factor (K)			
		0.02	0.05	0.8	1
MRI	Brain	52.743550	51.916029	42.421644	40.906702
	Spine	51.762781	50.319781	41.659953	39.145452
CT	Brain	51.337568	49.671462	41.004608	38.502050
	Spine	50.867533	48.624250	40.768540	36.134788

Table 3. Performance of the proposed method against noise attacks.

Image		Noise	Noise Level	NC	% BER
MRI	Brain	Salt and pepper	0.001	0.9850	0
			0.002	0.9380	0
CT	Brain		0.001	0.9751	0.0106
			0.002	0.9678	0.0267
MRI	Brain	Gaussian	M=0, V=0.00001	0.9487	8.3333
			M=0, V=0.00003	0.9168	10.9340
CT	Brain		M=0, V=0.00001	0.9932	9.6007
			M=0, V=0.00003	0.9781	10.5868
MRI	Brain	Speckle	V=0.00001	0.9532	5.1215
			V=0.00002	0.9526	7.1181
CT	Brain		V=0.00001	0.9983	5.1021
			V=0.00002	0.9963	7.1046

Table 4. NC and BER performance of the proposed method against signal processing attacks.

Attacks	NC		% BER	
	MRI Brain	CT Brain	MRI Brain	CT Brain
JPEG Compression (QF=65)	1.0000	1.0000	5.8002	0.03
Contrast Adjustment	0.7989	1.0000	5.7866	0.1527
Histogram Equalization	0.7498	0.7751	10.0059	6.1563
Gaussian LPF	0.7779	0.7349	11.1540	10.2817
Rotation (0.01 rad)	0.6981	0.6987	11.5634	11.2817
Cropping	0.6963	0.6657	13.0028	12.0176

Table 5. Encryption and decryption time for different texts.

P	Q	Encryption time(in sec)				Decryption time (in sec)			
		EPR 1 (89 B)	EPR 2 (110 B)	EPR 3 (150 B)	EPR4 (260 B)	EPR 1 (89 B)	EPR 2 (110 B)	EPR 3 (150 B)	EPR 4 (260 B)
43	47	0.1563	0.1719	0.2564	0.2867	0.2500	0.265625	0.3564	0.3867
89	97	0.2701	0.2786	0.3513	0.3689	0.3700	0.3900	0.4377	0.4798
131	113	0.4856	0.4999	0.5105	0.5288	0.6066	0.6589	0.7466	0.7534

4. Conclusion

In this paper, the proposed watermarking method based on DWT and DCT to embed multiple watermark into the cover image. For the identity authentication purpose, the method is used multiple watermarking in the form of text and image. The medical image is taken as cover image, the more robust and confidential EPR data is embedded into NROI region and less robust logo image is embedded to the ROI region of the cover image.In addition, the EPR data is encrypted by using the RSA method before embedding into the cover. From the simulated results, it is verified that the proposed algorithm is robust against the various signal processing attacks and also have good imperceptibility indicating the high quality of the watermarked image. This may provide a potential solution to existing telemedicine security problem of patient identity embezzlement.

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