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C14. Robust Watermarking Scheme for Telemedicine Applications

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ABSTRACT

This paper presents a blind watermarking algorithm for medical images and medical video frames based on Principle Component Analysis (PCA) and Digital Wavelet Transform (DWT). Quantization Index Modulation (QIM) is used as a method for blindness of our scheme. Different types of medical video frames are used in the evaluation process such as MRI, CT, Ultrasound and X-Rays. Experimental results show high imperceptibility where there is no noticeable difference between the watermarked video frames and the original frames (PSNR ≈ 51 dB). By varying the watermark size, high capacity watermark is achieved without affecting the quality of the medical frame. The performance of the proposed scheme is investigated when varying the impact factor and the compression rate. Simulation results indicate that the proposed algorithm achieves high robustness against compression and higher watermark capacity.

Keywords: Discrete Wavelet Transform, Principle Component Analysis, Medical Image Watermarking

I. INTRODUCTION

Telemedicine is a new medical application part of health aid field. Recently, achieving the correct medical diagnostic becomes very difficult decision because of the rapid development of diseases which needs cooperation of several medical organizations. Telemedicine is the exchanging of medical data over the open channels in order to achieving the correct medical diagnostic. Sharing Electronic Patient Record (EPR) over the networks requires three characteristics: authentication, integration, and confidentiality [1]-[3].

Digital watermarking techniques can play a significant role in health data management systems to protect the privacy and secrecy of medical data, controlling the access and the retrieval of the data, and maintaining their integrity. Several medical imaging techniques are used in diagnostic decisions such as: Magnetic Resonance Imaging (MRI), Computer Tomography (CT), Ultrasound, and X-Rays. A watermark containing medical information such as (patient record, hospital signature, and medical diagnostic) can be embedded into these images when sharing it through the network. The quality of the medical image is very important in correct diagnostic process so extreme care must be considered when watermark embedding process takes place. Imperceptibility, robustness against attacks, and high watermark capacity are fundamental issues in watermarking of images and videos [4]. Watermark can be embedded either in the spatial domain [5] or in the transform domain [6[, [7].

Many wavelet based watermarking schemes were proposed for medical images because of its compatibility with the HVS model. Giakoumaki *et al.* propose in [8] a wavelet based algorithm embeds multiple watermarks into medical images in order to serving in the authentication of doctor's digital signature and in the integrity control of the data. In the work proposed by Khamlichi *et al.* [9], a combined technique for embedding the patient data record directly into mammography images for tamper detection is introduced. The algorithm depends on the LSB technique and uses the mean value of the second and third order moments as effective tamper detection method. Edge map technique is used to localize the alteration place. The Wavelet Transform is used in a medical image watermarking technique proposed in [10] for the service of neurological diseases. Information about patients is transmitted to doctor's mobile phone by embedding the medical information inside diagnostic images. Raúl *et al.* [11] proposes watermarking scheme that combines data compression, encryption and watermarking techniques and image moment theory applied to radiological medical images. He uses the DICOM (Digital Imaging and Communications in Medicine) file contains a header (which stores information about the patient's name, the type of scan, image dimension, etc.) as a watermark to be embedded in medical images extracted from the DICOM file. Independent Component Analysis and Ridgelet transform for watermarking baby scan image is proposed in [12]. Ridgelet transform is a good method for enhancing edges and reducing noise. In [13], discrete wavelet transform is used to protect the copyright of digital signature of medical images. The watermark was embedded into the high frequency HL and LH sub-bands. The watermark digital signature is processed into a checked board image with black and white squares before embedding process. The robustness of this algorithm is tested using different filtering techniques. Hajjaji *et al.* presents an approach for watermarking medical images using the techniques of Code Division Multiple Access (CDMA), Discrete Wavelet transform (DWT) and Error Correcting Code (ECC) [14]. This algorithm embeds 1536 bits in different types of images (Echography and IRM) and achieving a good result in terms of watermarked image quality and robustness against JPEG compression and Gaussian noise attacks. Kumar *et al.* [15] proposes a high capacity scheme for using in telemedicine application. His algorithm is based on Haar wavelet transform of radiological images. Spread spectrum is used for embedding medical information into radiological images based on pseudo-random sequence pairs. A watermarking algorithm based on LSB (Least Significant Bit) of medical images to check the security issues of patient data sharing is proposed in [16]. Harris corner detector is used for selecting the important feature points in the medical image. Secure Hash Algorithm (SHA) is used to generate the hospital signature then the massage is coded by turbo coding in order to be robust against different attacks. Our proposed scheme depends on using principle component analysis to detect significant regions in the frame. Embedding watermark in these regions grantee robustness against attacks while keeping the quality of the image preserved. Medical data sharing requires high payload watermarks so the proposed algorithm is evaluated when different watermark sizes were used. This paper is organized as follows: section 2 presents the proposed watermarking scheme. Section 3 introduces the experimental results and the conclusion is given in section 4.

II. PROPOSED WATERMARKING SCHEME

The proposed hybrid watermarking scheme is based on the combination of DWT, PCA and QIM.

A. Data Embedding Process

Step 1: Divide video into frames (2Nx2N), and then convert RGB frames to YUV frames.

Step 2: Choose the luminance component Y of each frame and apply DWT on it. This result in four multi-resolutions sub-bands (NxN): LL1, HL1, LH1, and HH1. For each band apply DWT again to get 16 sub-bands (N/2xN/2). For each band in the 16 sub-bands, apply one more DWT to get 64 sub-bands each is (N/4xN/4).

Step 3: Divide each sub-band I_s with N/4xN/4 dimension into nxn non-overlapping blocks where the number of blocks is k = (N/4xN/4)/(nxn).

Step 4: Calculate the entropy E_n of each nxn block in each sub-band I_s, where the entropy is defined as a statistical measure of randomness that can be used to characterize the texture of the input image:

$$E_n = -\sum(P.^{x}\, log2(P)) \quad (1)$$

Where, p contains the histogram counts, and the operator ($.^{X}$) means multiplication of each element of matrix A with its corresponding element of matrix B.

Step 5: Select maximum entropy blocks which are the edges blocks of the frame. The position of these selected blocks is saved to be used in the extraction process and can be considered as a secret key. Apply PCA to each selected block as described.

1. For each selected block B_{si} (nxn) compute the mean of the block m_i , where B_{si} represent block number i in each sub-band I_s. Then get the block zero mean A_i as follows:

$$A_i = E(B_{si} - m_i) \quad (2)$$

2. For each selected block, calculate the covariance matrix C_i of the zero mean block A_i as:

$$C_i = A_i \times A_i^T \quad (3)$$

   Where T denotes the matrix transpose operation.

3. Transform each block into PCA components by calculating the eigenvectors corresponding to eigenvalues of the covariance matrix:

$$C_i\phi = \lambda_i\phi \quad (4)$$

   Where ϕ is the matrix of eigenvectors and λ is the matrix of eigenvalues.

4. Compute the PCA transformation of each block to get a block of uncorrelated coefficients by:

$$Y_i = \phi^T A_i \quad (5)$$

Where Y_i is the principle component of the i^th block.

Step 6: For building the QIM quantizer, two uniform quantizers q0 and q1 are required to apply Eq. 6. These quantizers must be defined in the range of the maximum and minimum values of the principle components of the entropy selected blocks all over each wavelet sub-band. Select the minimum value in that range to be q0 then q1 will be as follows:

$$q_1(x) = q_0(x) + \frac{\Delta}{2} \quad (6)$$

where Δ is the step size of the quantizers.

Step 7: Convert the RGB 32x32 watermark image to (1,-1) binary image. Convert the binary image into a vector W = {w1, w2,……, w32x32} of zeros and ones.

Step 8: Divide the vector W into 64 parts p_1, p_2, p_3, and p_{64}. Each watermark part P_i is embedded in each corresponding sub-band I_s. The number of the selected maximum entropy blocks is equal to the number of the bits in each watermark part P_i. The watermark bits are embedded with strength α into the maximum coefficient M_i of each PC block Y_i. For embedding process, if the watermark value is 1 (resp. 1) each element M_i is quantized with q_0 which has the minimum distance from M_i and if -1 (resp. 0) is to be embedded then M_i is quantized with q_1.

$$M_i' = Q + \alpha W \quad (7)$$

Where, Q is corresponding to q0 or q1 and α is the watermark embedding strength (Impact factor). Q is saved as a second key for using in the extraction process. The value of α in this algorithm is 9 for all selected wavelet bands. If the watermark bit is 1 then adding α to the maximum coefficient in the Y block but if it is zero, then α is subtracted from the same coefficient.

Step 9: Apply inverse PCA on the modified PC block Y_i' to obtain the modified wavelet block by using:

$$A_i = \phi Y_i' \quad (8)$$

Step 10: Apply the inverse DWT to obtain the watermarked luminance component of the frame. Finally reconstruct the RGB watermarked frame and obtain the watermarked video.

B. Data Extraction Process

The steps used for watermark extraction is the same as the steps in the embedding but no need for the original video sequence. Only the watermarked video and the two secret keys are required for the extraction procedure.
Step 1: Convert the watermarked video into frames. Each RGB frame is converted to YUV representation.

Step 2: For each Y component, apply DWT to decompose Y into 64 multi-resolution sub-bands. Divide each sub-band into nxn non-overlapping blocks.

Step 3: Using the first secret key we can get the watermarked blocks. Apply PCA transformation for each block as described in the embedding procedure.

Step 4: By using the second secret key we can extract the watermark by applying the following equation:

$$W' = \frac{M_i' - Q}{\alpha} \quad (9)$$

Step 5: The extracted watermark is compared with the original watermark by computing the similarity measure between them as follows:

$$NC = \frac{\sum_i \sum_j W(i,j).W'(i,j)}{\sum_i \sum_j W(i,j)^2} \quad (10)$$

Where, NC is the normalized correlation. NC value is 1 when the watermark and the extracted watermark are identical and zero if the two are totally different from each other.

III. EXPERIMENTAL RESULTS

Performance of our proposed algorithm was tested for the telemedicine application use. The test was carried out using 4 types of medical video frames which are MRI, CT, X-Rays and Ultrasound. The size of the used frame is 512x512. The watermark is a binary image of size 32x32. The algorithm is evaluated when varying the watermark embedding strength (the gain factor) and the size of the watermark. For evaluating the performance of any watermarking system, Peak Signal to Noise Ratio (PSNR) is used as a common measure of the visual quality of the watermarking system. To calculate the PSNR, first the Mean Square Error (MSE) between the original and watermarked frame is computed as follows:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - I'(i,j)]^2 \qquad (11)$$

Where M, N are the size of the frame, and I(i, j), I'(i, j) are the pixel values at location (i, j) of the original and watermarked frames. Then, PSNR is defined as:

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \qquad (12)$$

Extracted watermark is evaluated by measuring its correlation with the original watermark. The luminance components of the first 100 frames of each medical video type are watermarked using the proposed scheme. The original sampled frame and its corresponding watermarked frame where no attacks were applied are shown in Fig. 1 for all videos.

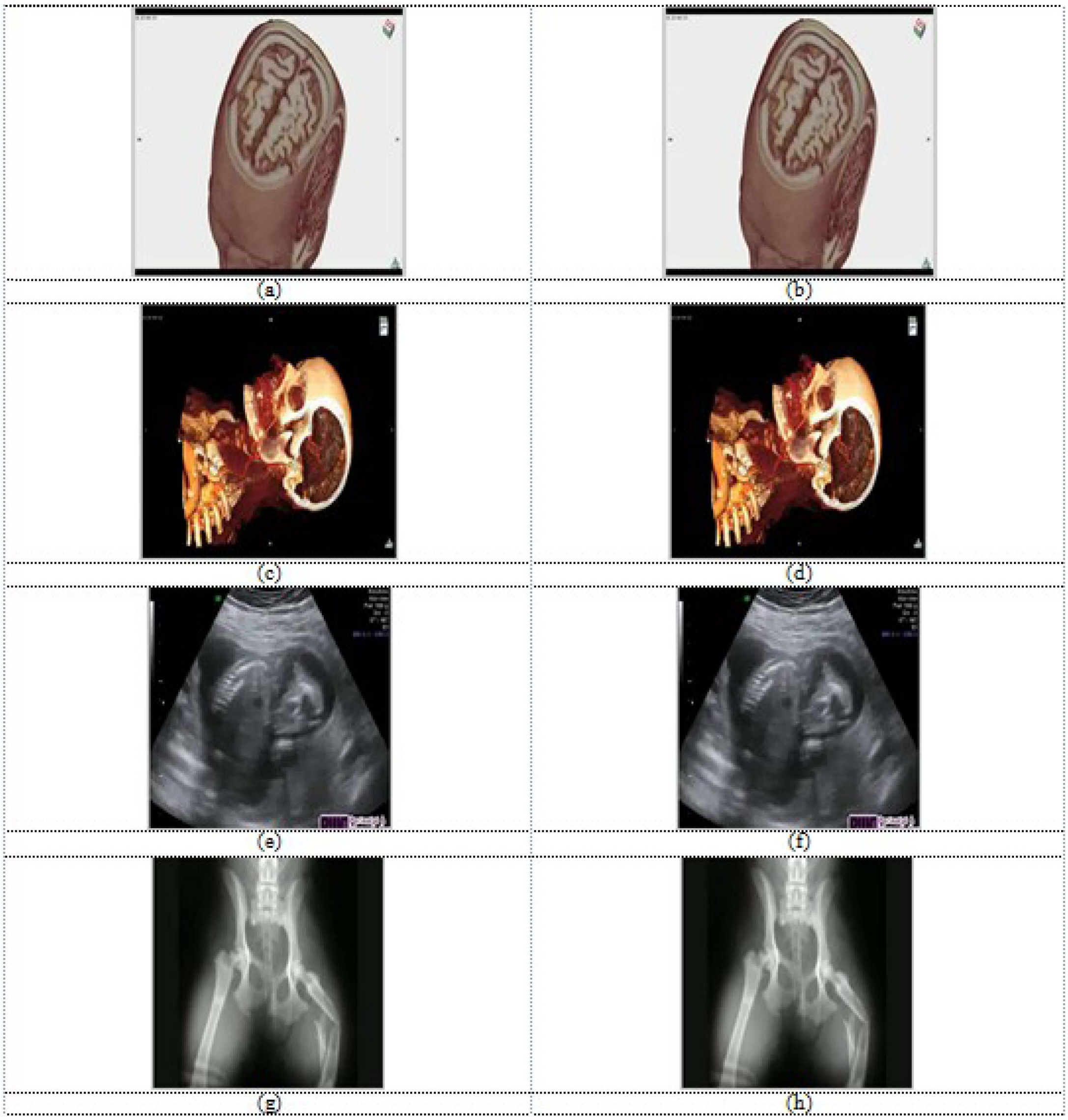


Fig. 1: Original (left) and watermarked (right) frames: (a) MRI, (c) CT scan, (e) Ultrasound, and (g) X-Rays videos.

Table 1: PSNR of Watermarked Video Frames

	Video Type			
	MRI	*CT scan*	*Ultrasound*	*X-rays*
PSNR	51.9951	51.8861	51.7595	53.9717

The measured average PSNR are almost between 51 db and 54db and are registered in Table 1. The watermarked frames appear visually identical to the original frames. The quality of x-ray video frames is the maximum quality where the average PSNR achieves 53.9717 db. The original watermark and the extracted watermarks from each video frame are shown in Fig 2. It is clear that, all extracted watermarks can be identified easily and the NC values are higher than 0.9 which considered a perfect NC value.

(a)




NC =0.9479 NC=0.9323 NC=0.9549 NC=0.9844

(b) (c) (d) (e)

Fig. 2: (a) Original watermark, and extracted watermarks from videos (b) MRI, (c) CT scan, (d) Ultrasound, (e) X-rays.

To show the effect of the impact factor, the proposed algorithm was applied at different values of the impact factor. Figure 3 shows the variation of the PSNR with respect to the impact factor. It is clear that, as the impact factor increases the PSNR decreases for all kinds of the medical video frames. Figure 4 shows the variation of NC with respect to impact factor variation. As the impact factor value increases, correlation between original watermarks and extracted one increase which means that the robustness of the algorithm increase. From these two figures, the X-ray medical video is capable of getting higher impact factor values while keeping the PSNR in higher range from 50 to 60 (when impact factor is 15). Also the X-ray gives higher NC values.

The proposed scheme was tested in case of increasing the watermark payload (watermark capacity). Large medical data may be needed to be embedded in host video frames. A comparison between different medical video frames has been done to indicate which type of medical imaging technique can store more watermark capacity. Figure 5 illustrates the extracted watermarks of different sizes 16x16, 32x32, 64x64, and 128x128. As the watermark size increase the PSNR of the watermarked frame decrease and the opposite for the NC value. It is clear from Fig. 5 that as the watermark size increases; the identification of the watermark during the extraction process becomes clearer. The extracted watermark from X-ray medical frames is the best. Increasing the watermark size embedded into 512x512 different medical video frames from 16x16 to 128x128 will decrease the average PSNR from almost 65db to 35db as shown in Fig. 6. X-ray frame is best one for embedding bigger watermark while keeping PSNR in a good range. CT scan is the next kind of frames that can get a large watermark size without degrading the quality of the scan.

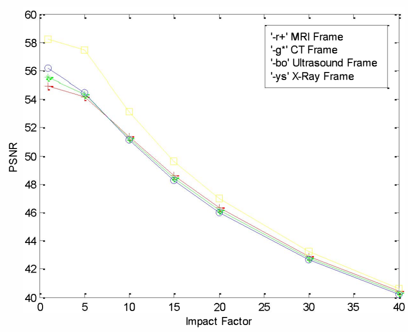


Fig. 3: PSNR versus impact factor.

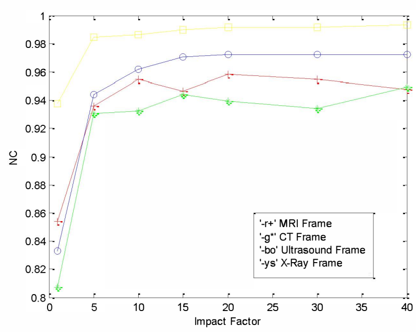


Fig. 4: NC versus impact factor.

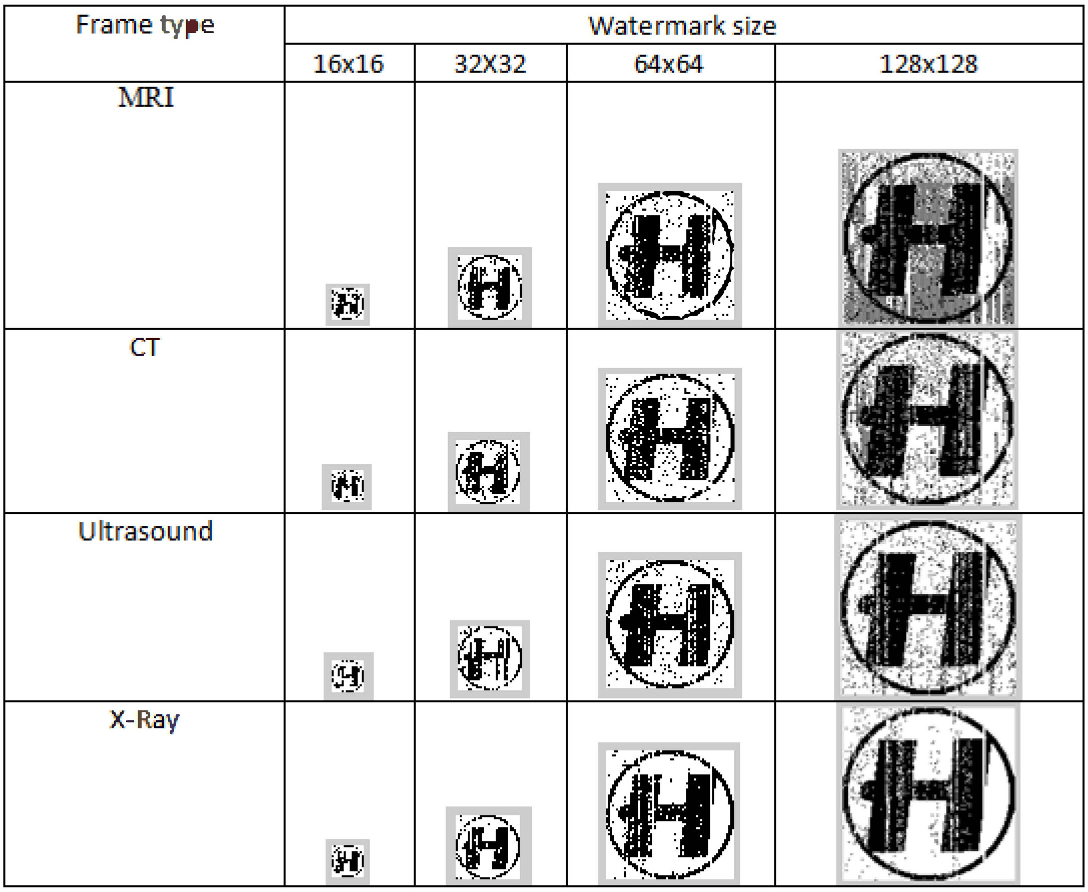


Fig. 5 Extracted watermarks of different sizes for different medical videos.

Increasing the watermark size doesn't improve the correlation value between the original and the extracted watermarks as shown in Fig. 7. The variation observed in the NC values coming from the variation of the types of medical frames. The NC value and the visual observation of the extracted watermark are both important in the evaluation process. Figure 8 shows that, at certain value of watermark size the PSNR increasing with the increasing of the frame size. MRI frames were used and the result will be the same for all used medical videos. In our algorithm, increasing the medical frame size allow bigger watermark to be hidden into the frame without decreasing the PSNR. If the frame size is 256x256 the watermark size can be varied from 16x16 to 64x64. In case of higher frame size watermark size can be varied considering the segmentation process of the frame and the watermark.

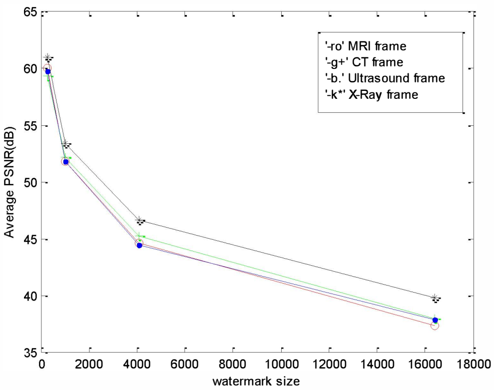


Fig. 6: watermark capacity versus PSNR.

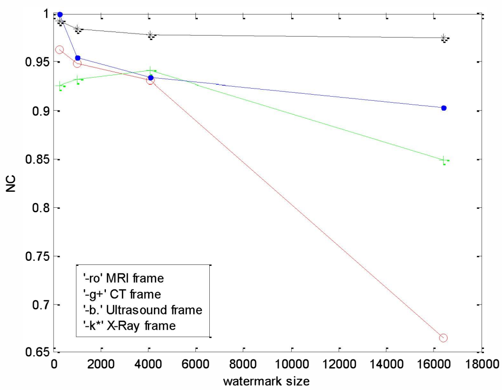


Fig. 7: Watermark capacity versus NC.

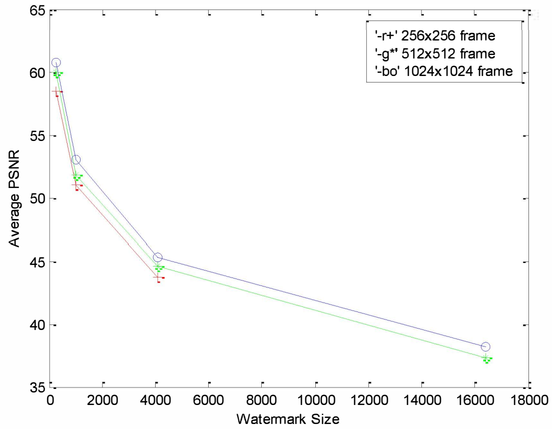
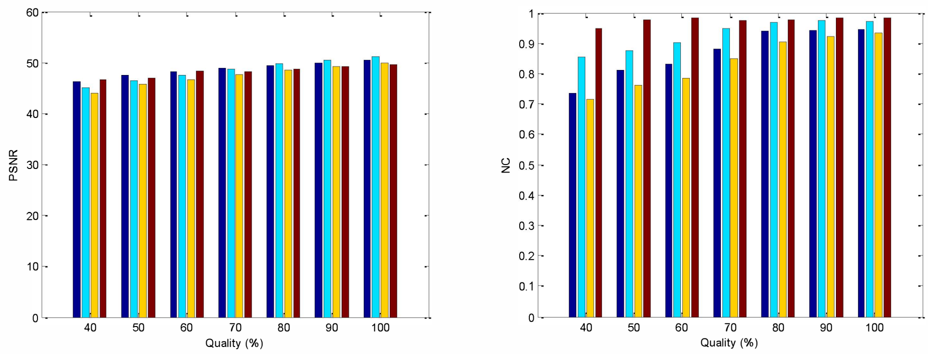
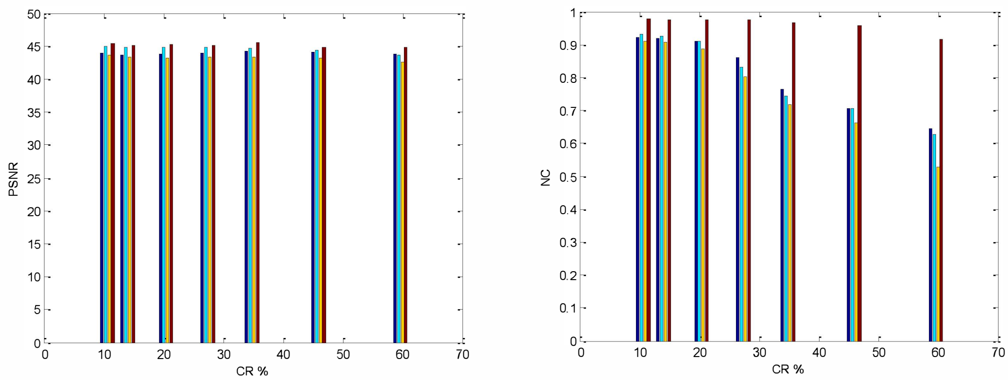


Fig. 8: Average PSNR for multiple MRI frame size at different values of watermark size.



(a) (b)

Fig. 9: (a) PSNR for compressed watermarked frames versus quality, (b) corresponding NC values versus quality. (MRI (blue), CT (green), Ultrasound (yellow), and X-Ray (red))



(a) (b)

Fig. 10: (a) PSNR for medical compressed watermarked frames versus CR, (b) corresponding NC values versus CR: MRI (blue), CT (green), Ultrasound (yellow), and X-Ray (red).

Figure 9(a) shows the PSNR of medical watermarked frames against JPEG attacks at different qualities using 32x32 watermark image. It should be noted that until quality 40%, the PSNR value still between 40 to 50 dB which means that the images do not loss its aspect psyche visual. Also, the NC is plotted against qualities of JPEG attacks in Fig. 9(b). It is clear that at 60% compression, the NC values of medical frames do not go under 0.7 which means that the watermark can be extracted clearly.

Figure 10 shows the performance of our scheme against JPEG attacks at different compression ratios using 64x64 watermark image. In Fig. 10(a) the PSNR values exceed 45 dB at a compression ratio near to 60%. It is clear that for a compression ratio from 10% to 60%, the robustness of our scheme against JPEG compression is very high and images do not lose their visual characteristics. Figure 10 (b) shows the NC values for the compressed images. For CR from 10% to 60% the NC does not go below 0.5 which means high possibility of extracting the watermark. It is shown that x-ray medical images give higher performance than other medical images. Comparing our results with the results proposed by Hajjaji [16] it clear that, he embeds 425 bits as medical information and after coding the total embedded bits become 1700 bits. Hajjaji cleared that at compression ratio 50% the PSNR of his scheme was nearly 35 dB which means better performance of our scheme.

Table 2 indicates that our proposed algorithm is performing better than the scheme in [15] regarding capacity and impact factor. Our algorithm can allow much more medical information to be embedded in medical images while keeping the quality and the robustness in good ranges.

Table 2: Capacity and Impact factor Comparison.

	Proposed Algorithm	***Kumar [15]***
Capacity (Payload)	128x128 (exceed 35 db)	40x80 (30.2084db)
Impact factor	40 (exceed 35 db)	40 (21.5375)

Finally, the time required for extracting the watermark from one video frame approximately equal to 2 sec using Cor(TM) 2 Duo cpu 2.00 GHz and RAM 1.00 GB.

IV. Conclusion

This paper presented a high capacity watermarking scheme which can be used in telemedicine applications. The algorithm depends on DWT in conjunction with PCA transform. Binary watermark represent medical information has been embedded into medical video frames using QIM. Different radiological video frames were used. Our scheme is imperceptible and robust against several attacks and has a good performance compared with previous medical schemes.

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