A Hybrid Secure watermarking technique in Telemedicine

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Abstract— **For healthcare applications, a hybrid multiple watermarking has been projected in this paper. For authentication and identity purpose, the projected scheme makes use of two watermarks, one in the form of text watermark which includes diagnostic information of the patient and the other image watermark includes the hospital logo. In order to improve the robustness performance of the scheme DWT, DCT and SVD is applied while inserting the multiple watermarks to reduce the noise effects on the watermarked image. The security of the text and image watermark is enhanced by using Arithmetic coding and Arnold transform respectively before inserting into the original medical image. Various experiments have been carried out on different medical imaging modalities to estimate the performance of the projected scheme in terms of imperceptibility, robustness and security even after different types of attacks.**

Keyword - Discrete wavelet transforms, Discrete cosine transform, Singular value decomposition, Authentication, Telemedicine.

I. INTRODUCTION

Telemedicine eradicates distance barrier and affords entrée to medical services obtainable at far-away places. It permits transmission of medical data from one position to another and facilitates handy and accurate interfaces among patients and medical staff. Circulation of medical images enforces significant prerequisite that the medical images were not adapted by illegal users. This precondition is called preserving integrity of medical images. On the contrary, transmission of medical image and patient data autonomously through commercial networks guides to more cost and transmission time [1]. Watermarking is employed to deal with the above two concerns. Digital watermarking is the current, admired and competent scheme for the safety of multimedia data. In this scheme watermark is embedded into the digital data to protect it from unauthorized use. Digital watermarking has diverse applications such as copyright protection, copy protection, tamper detection, broadcast monitoring, content archiving, fingerprinting, healthcare, cyber watermarking, digital cinema and content authentication. Medical image watermarking has various benefits such as accumulation of storage space and bandwidth necessities, privacy of patient data [2, 3]. Additionally, medical image watermarking also assists in reducing medical identity thefts which are the serious safety issues reported in a variety of investigations [2, 3, 4]. The major anxiety of digital image watermarking schemes is that the watermark should not influence the visual quality of the original medical image and it should be robust towards dissimilar signal processing attacks.

Based on the domain used for hiding data within an image, watermarking techniques are organized into two categories, namely, spatial domain and frequency domain. Information is straightforwardly inserted into original image in spatial domain watermarking techniques [5–8]. In frequency domain techniques [9–11], information is inserted into transformed original image. One more categorization of watermarking schemes is reversible and irreversible schemes. In reversible watermarking techniques [10–13] the original image can be attained without loss from watermarked image, whereas lossless retrieval of original image is not feasible with irreversible watermarking schemes [9]. Reversible watermarking is more appropriate for medical images [14].Robustness, imperceptibility, capacity, computational cost and safety are essential characteristics for wide-ranging watermarking system [15]. Conversely there subsists some trade off among robustness, imperceptibility and payload characteristics of the watermark. As a result, some optimization procedures are needed to stabilize these characteristics. The majority of the medical images enclose two divisions called ROI and RONI. From diagnosis point of analysis ROI part is more significant. Care should be taken during hiding data into ROI region so that visual quality will not be demeaned. Simultaneously any tampering with ROI must be recognized and the original ROI must be retrieved in order to evade misdiagnosis as well as retransmission of medical image. The recovery data of ROI is generally inserted into RONI [6–8, 8, 16–18]. Once any tamper is identified in ROI of received watermarked medical image the tampered area of ROI is restored with the recovery data inserted in RONI.

The rest of the proposal is planned in the following way. State-of-the-art medical image watermarking schemes are inspected under related works in the subsequent section.. The Projected scheme is discussed with regard to the procedure of insertion and extraction of the multiple watermarks on medical images in section 3. Analysis of the simulation results are proved by applying different attacks, which may take place deliberately or accidentally onto the medical image and are examined with the imperceptibility and robustness of the proposal against different attacks in section 4. Ultimately Section 5 concludes the scheme.

II. RELATED WORK

Terzija et al. [19] projected a scheme for improving the effectiveness and robustness of the image watermarks using three different error correction codes (ECCs). Out of the three Error Correction Codes, Reed-Solomon code presents better than the BCH as well as Hamming code. The simulation results show that the scheme is robust for dissimilar attacks. Conversely, the method is unable to rectify the error rates superior than 20 %. A DWT-SVD based image watermarking scheme is proposed by Lai et al.[20], where the watermark data is straightly inserted into the singular vector of the original image's DWT sub-bands. The simulation results shows that the scheme is robust for dissimilar types of attacks at suitable visual quality of the watermarked image. Rosiyadi et al. [21] projected a hybrid watermarking method for the copyright protection which uses DCT and SVD. In this scheme, DCT is exploited on the original image employing the zigzag space-filling curve for the DCT coefficients and afterward SVD is applied on the DCT coefficients. Lastly, the original image is adapted by the left singular vectors and the singular values of the DCT coefficients while inserting the watermark image. In this scheme, Genetic Algorithm(GA) is exercised to identify the optimization scaling factor of the watermark image. Simulation results shows that the planned method is robust in opposition to numerous types of attacks. The similarity among the method based on DCT and SVD utilizing GA and the hybrid method based on DCT-SVD has been planned by Rosiyadi et al. in [22]. It is revealed that the robustness of the retrieved watermark and the visual quality of the watermarked image of the process using GA scheme is healthier than the hybrid method.

In recent times, the superior robustness of watermark has been accomplished by exploiting wavelet based watermarking as given in [23,24]. The performance of the wavelet based watermarking scheme depends seriously on insertion and retrieval procedure. The major benefits of wavelet transform schemes for watermarking applications are: space frequency localization, multi-resolution illustration, multi-scale analysis, flexibility and linear complexity. The wavelet based watermarking is also well-matched with the novel image standard JPEG 2000. Further, performance development of the watermarking schemes by exploiting hybrid watermarking has been projected by some investigators [25, 26, 27–29, 30, 31]

III.PROPOSED SCHEME

The projected multilevel watermarking of medical images inserts multiple watermarks in the form of text and image into original medical image. The allotment of image and text watermarks according to robustness and capacity requirements at dissimilar DWT sub-bands are as follows: LH2 Contains Patient's history and diagnostic reports related information along with Doctor's Identification code and HL2 contains hospital logo for the purpose of Authentication. It is obvious that watermarks including significant information and involving more robustness are inserted in higher level DWT sub-bands [32, 33]. In this work, information of the patient and hospital logo are inserted in the original medical image. In the insertion process, the original medical image is decomposed into two-level DWT. Low-high frequency band (LH2) of the second level DWT is altered by DCT and subsequently SVD is applied to DCT coefficients. The image as well as text watermark is also altered by DCT and SVD. Then the obtained singular values of the two watermarks are inserted in the singular values of the original medical image. The hospital logo and the patient's information are inserted in to the HL2 and LH2 DWT sub-band of the original medical image. Further, the information of the patient watermark is compressed by lossless arithmetic encoding technique prior to inserting into the original medical image which offers the additional level of protection. Besides, the hospital logo is scrambled by using Arnold transform for improving the robustness and reducing the channel distortion respectively. The compressed text watermarks are then inserted into the original medical image. Results are acquired by simulating on dissimilar medical image modalities. Simulation results are given to demonstrate that the projected scheme is capable to survive different types of attacks. The projected algorithm has two disparate parts, the insertion and retrieval procedure which are elucidated as follows..

A. Embedding Procedure for text watermark image

1. Two-level DWT transform is applied on original medical image to decompose it into subsequent sub bands and opt for LH2 sub-band among the sub bands.

2. DCT is applied to the preferred sub-band and then relate SVD to the transformed DCT coefficients to acquire resultant three matrices U, D and V.

$$X_o = U_o D_o {V_o}^T \qquad (1)$$

3.Compress the patients information text watermark image using Arithmetic encoding technique.

4. Apply DCT on the compressed watermark image and then apply SVD to DCT coefficients to obtain corresponding matrices similar to step 2.

$$X_w = U_w D_w {V_w}^T \qquad (2)$$

5. Amend the singular values of LH1 sub band of original medical image with the singular values of text watermark image .

$$D_{watimg} = D_w + c * Sig_w \qquad (3)$$

Here 'c' is defined as the scaling factor with which watermark images are inserted into original medical image.

6. Obtain modified DCT coefficients by applying Inverse Singular Value Decomposition (ISVD) using following equations.

$$X_{watimg} = U_o * D_{wimg} * V_O{}^T \qquad (4)$$

7. Obtain modified LH2* sub band by applying Inverse Discrete Cosine Transform (IDCT) to modified DCT coefficients

8. Change LH2 sub band of original medical image with the modified LH2* sub band and apply Inverse Discrete Wavelet Transform (IDWT) to get watermarked image.

9. Apply attacks and noise to the watermarked image to check the robustness of the proposed algorithm.

B. Retrieval Procedure for text watermark image

1. Two-level DWT transform is applied on original medical image to decompose it into corresponding sub bands and choose LH2 sub band among the sub bands.

2. DCT is applied to the preferred sub-band and then relate SVD to the altered DCT coefficients to acquire their equivalent three matrices U, D and V

$$X_o = U_o D_o V_o{}^T \qquad (5)$$

3. DCT is applied on the watermark image (patient's information) and then apply SVD to DCT coefficients to acquire their equivalent matrices like step 2.

$$X_w = U_w D_w V_w{}^T \qquad (6)$$

4. Step 1 and step 2 are applied to watermarked image to acquire its equivalent SVD Matrices for LH2 sub band

$$X_{wimg} = U_{wimg} D_{wimg} V_{wimg}{}^T \qquad (7)$$

5. Singular values of watermark image are acquired from the singular values of LH2 sub band of watermarked image and original medical image respectively by exercising the equation (8).

$$Sig_w = \frac{(D_{wimg} - D_w)}{c} \qquad (8)$$

6. Watermark is retrieved by exploiting inverse Singular Value Decomposition (ISVD) using equation (9) as well as the inverse Discrete Cosine Transform (IDCT).

$$X_{ow} = U_w * Sig_w * V_w{}^T \qquad (9)$$

7. Decompress the retrieved watermark by exploiting the inverse Arithmetic coding to obtain the original watermark image (patient's information).

The same above specified procedure is followed during insertion and retrieval of the image watermark (hospital logo) into the original medical image but it is done in the HL2 sub band of DWT after applying Arnold transform on the hospital logo watermark image for enhancing robustness, imperceptibility as well as security.

IV.EXPERIMENTAL RESULTS AND ANALYSIS

The performance of the amalgamated DWT-DCT-SVD watermarking scheme has been assessed in terms of quality of the watermarked image (PSNR) and robustness of the watermarked image (NC). The medical CT-scan gray-scale image of size 512 ×512 as original image, the watermark image of size 256 × 256 and 128×128 is considered as text watermark (patient's information) and image watermark (hospital logo) respectively while simulation. The protection of the text watermark image is boosted by exploiting Arithmetic coding technique prior to inserting into the original medical image. In addition, Arnold transform is applied on the hospital logo to increase the authentication for correctly retrieving the watermark during diagnosis. For testing the robustness of the retrieved watermarks (both image and text) and the imperceptibility of the watermarked medical image, MATLAB is executed. Figure 1a and b shows the text watermark and image watermark respectively which are inserted during watermarking process. The original and watermarked CT-Scan image of human brain is shown in Figure 2a and b. The PSNR and NC performance of the projected scheme is shown in Tables 1 and 2.

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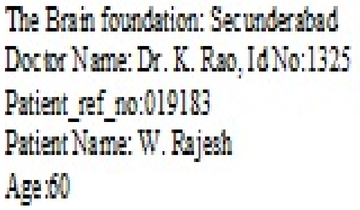
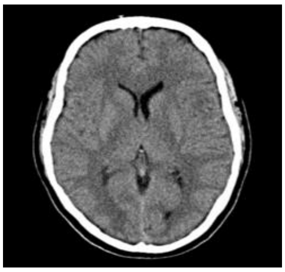


Fig.1(a) Patient's information (b)Hospital logo



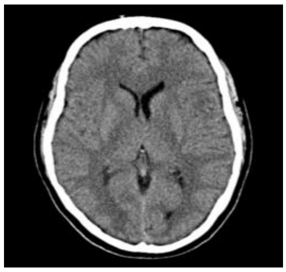


Fig.2.(a) Original and b) Watermarked CT-Scan of Human brain

Table 1 shows the PSNR and NC performance of the projected method without attacks for six different medical images. The highest NC value (1) have been obtained with MRI image. However the minimum NC value is 0.92 for X-Ray image. In Table 2, the PSNR and NC performance of the projected method has been assessed with different types of attacks. The maximum PSNR value obtained even after attacks is 56.9 dB and NC value is 0.97. Table 3 shows the comparison of the PSNR and NC performance of the projected method with [34]. The maximum NC value obtained by the Singh et al. [34] is 0.93. However, the maximum NC value obtained by the projected method is 0.98. Thus the projected method offer higher robustness and imperceptibility than [34].

Table 1. PSNR and NC values for different Medical images

Medical Images	PSNR (db)	NC
Ultrasound	56.75	0.94
MRI	57.9	1
CT	57	0.96
Mammography	52.76	0.98
PET	54.8	0.93
X-RAY	55.13	0.92

Table 2. PSNR and NC values for CT-Scan of human brain Medical Image with various Attacks

Attacks	PSNR (db)	NC
Resizing	52.75	0.91
Rotation	54.9	0.97
Cropping	53.97	0.93
JPEG Compression	49.99	0.94
Sharpening	53.8	0.89
Averaging	54.14	0.86
Salt &Pepper noise	55.83	0.95
Gaussian noise	56.9	0.92

Table 3. Comparison of PSNR and NC results for CT-Scan of human brain Medical Image with [34]

Attacks	Proposed method		[34]	
	PSNR (db)	NC	PSNR (db)	NC
Resizing	54.75	0.91	50.12	0.89
Rotation	56.9	0.99	51.03	0.9
Cropping	56.97	0.93	49.98	0.92
JPEG Compression	52.76	0.94	49.99	0.91
Sharpening	53.8	0.89	50.93	083
Averaging	54.14	0.86	48.78	0.84
Salt &Pepper noise	55.83	0.95	52.45	0.93
Gaussian noise	56.9	0.92	51.89	0.85

V. CONCLUSION

In this proposal different transforms such as DWT, DCT and SVD were combined to progress the robustness of the watermarks, at the same time the visual quality of the watermarked image as well as the capacity and security of the watermarks is the chief objective of the research. Thus Security and confidentiality are recommended by scrambling one of the watermark image (hospital logo) using Arnold transforms and by applying lossless arithmetic coding to the other watermark which is text watermark image for bit compactness before inserting into the original medical image. At last, the visual quality of the watermarked image is estimated by the subjective method also. On the whole, the projected method is superior than the other reported schemes in terms of robustness and imperceptibility even after different types of attacks. Therefore, projected method offers a valuable result for the prevention of patient identity theft in healthcare applications such as tele-ophthalmology, telemedicine, tele-diagnosis and tele-consultancy etc.

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