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An Efficient Contourlet Based Multiple Watermarking Scheme For Health Information System

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***Abstract*—** Health Information Systems (HIS) are gaining wide popularity in the recent days demanding digitization for easy storage of medical data in the secure environment that protects the patient privacy. As the medical data has been transferred on unsecure network authentication and integrity of medical data is a prime concern to attract the researchers. These objectives are gained by watermarking. Medical Image Watermarking (MIW) has recently evolved to solve the issues like storage, security and privacy related with HIS. This paper proposes an effective approach based on Contourlet Transform (CNT) for data hiding of medical records Electronic Patient Record (EPR), biographic signal like EEG or ECG and hospital logo. The contourlet transform is exploited in this research for its multiscale properties and predictive coding like ADM is proposed for compression of ECG signal. The medical text data is further encrypted using RSA public key algorithm. The efficacy of the developed approach is examined using various performance parameters (Peak Signal to Noise Ratio, PSNR and Structural Similarity Measure , SSIM).The Quality of extracted logo and recovered ECG is evaluated using Normalized Correlation Coefficient (NC) .The similarity of original and extracted EPR examined using Bit Error Rate (BER).Imperceptibility of algorithm is preserved as PSNR values are above 45 DB And MSSIM is greater than 0.98.The comparative analysis with other frequency domain techniques is presented which claims and confirms the superiority of proposed contourlet approach for efficient multiple watermarking in HIS.

***Keywords*—** Contourlet Transform; Watermarking ; Health Information system

I. INTRODUCTION

Health information System (HIS) demands the exchange of the medical history of the patient using unsafe networks which includes the clinical images, initial diagnosis, prescriptions & patient history. Revolutionary advancements in the domain of information technology have enthused growth of and expansion of HIS. This expansion has contributed to elevation of finest practice in medical conduct in telemedicine, Picture Archiving and Communication System (PACS), E-Health systems. It is obligatory to take appropriate measures to ensure that patient information is send to authentic people and integrity of data is preserved [1]. It is required to imbibe the aspects of confidentiality, authentication, integrity and saving bandwidth while distributing of these images in the HIS .

Digital watermarking is used to embed the information in the host signal (image, video etc.),is a popular technique amongst researchers for multimedia data management[2] .Digital watermarking for Medical images have the potential to address wide range of issues related with HIS and distribution. Sending the patient's credentials separately demands more bandwidth requirement so if data is hidden in the medical image it saves bandwidth requirement and also claims secure transmission while keeping authenticity [3,4].

Literature reports various methods to interleave patient credentials in the medical images. Spatial domain techniques [7,8,9] are less popular as they are fragile. Frequency domain techniques are therefore largely explored. The performance of DCT based data hiding technique is analyzed for interleaving medical data and records of the patients. The other researcher embeds the text and graphical signal using DCT from middle frequency range [8].Recently some transform domain MIW techniques are also studied but Contourlet Transform (CNT) has received less attention and needs further experimentation [10,11]. Most of the reported approaches are non-blind, fragile, with inadequate interleaving capabilities and are also inefficient in providing effective security measures needed in HIS standard.

This paper proposes an efficient approach under framework of CNT to hide the multiple watermarks including hospital logo, ECG signal which is encrypted and further also considers patient's history in the medical images. The proposed technique stores patient's credential in low

pass band of second level contourlet transform. The proposed scheme is tested for various medical image modalities and comparative results are summarized to prove the superiority of the proposed approach. Next Section presents a brief introduction on CNT and ECG encryption along with proposed interleaving scheme for MIW from the perspective of HIS. Section III details the experimental results of the proposed approach and summarizes the findings of comparative analysis with other popular frequency domain techniques to claim the superiority of proposed CNT based approach. The investigational results conforms the efficiency of the algorithm which is imperceptible and robust against expected attacks. The proposed approach uses multiple watermarking and the achieved encouraging results contribute in development of efficient HIS. Finally, this paper is concluded with discussion section at the end.

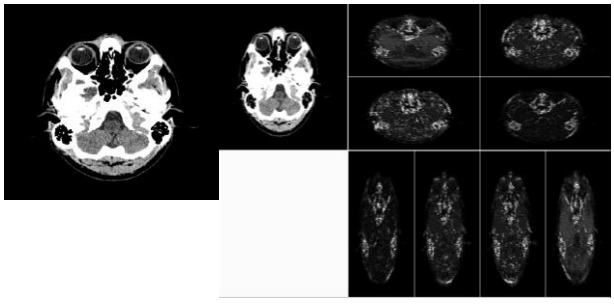
II. THE PROPOSED METHODOLOGY

The approach presented in this research explores two level- CNT and hides the patients credential using key based bit replacement technique. To provide the security EPR is encrypted using well known RSA public key algorithm. Biographic signal is compressed and encrypted using ADM.

A. Contourlet Transform

The contourlet transform [12], is a unique approach of decomposition of signal and was presented by Minh Do and Martin Vetterli. It is characterized by a malleable multi-directional, multi-resolution demonstration of an image. Laplacian Pyramid Decomposition (LPD) followed by Directional Filter Banks (DFB) is utilized for decomposition of the signal into low and high frequency sub-bands. Finally, the data is characterized as a set of directional sub-bands at manifold scales [13]. Contourlet is reported to be superior to wavelet as it represents geometrical smoothness of contours effectively [14].

Fig.1 (a) depicts an original test CT image and Fig. 1(b) details its corresponding two-level CNT. Fig.2 shows contourlet decomposition frame work.



(a)Original Image (b) 2 level CNT Coefficient image

Fig.1 Contourlet Transform (CNT) image

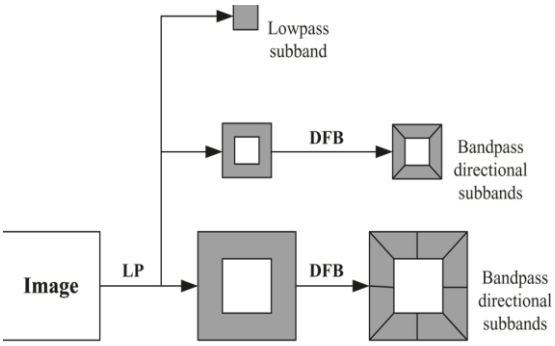


Fig.2 CNT decomposition framework

B. ECG encrption using Predictive coding technique

Encryption of ECG signal is important step in the proposed approach. Literature reports various predictive coding techniques. Differential Pulse Code Modulation (DPCM) and Adaptive Delta Modulation (ADM) are most popular techniques for signal compression and encryption [15].The original ECG signal is 16 bit which will be converted to 1 bit using ADM. As depicted in Fig.3, comparator relates present sample *x(k)* with the sample which is predicted in the process, $\widetilde{x_q}(k)$ to produce a signal, called prediction error $\varepsilon_q(k)$. This output depends on the step size and is marked as $\pm \Delta$, where Δ is defined as the size of the step. Prediction error is depicted as $\varepsilon_q(k)$. Fig. 3 details the annotations used and the process adopted.

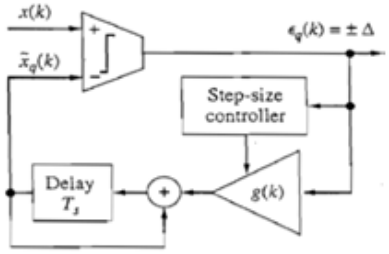


Fig.3 Outline for ADM functionality

The reported side effects of slope overload are addressed by variable step size controller in ADM. Additionally; adverse effects of noise (granular) are reduced due to flexible size of step controlled in ADM. The former and the current values of $\varepsilon_q(k)$ effect the value of gain. The gain of the controller plays a significant role and is changed by factor of K. The pre-defined range lies between one and two. The changes in the gain and the predicted sample is calculated as using the following equation eq.(1) and eq.(2) respectively.

$$g(k) = \begin{cases} g(k-1)xk & \varepsilon_q(k) = \varepsilon_q(k-1) \\ g(k-1)/k & \varepsilon_q(k) \neq \varepsilon_q(k-1) \end{cases} \quad (1)$$

$$\widetilde{x_q}(k) = \widetilde{x_q}(k-1) + g(k-1) * \varepsilon_q(k\text{-}1) \quad (2)$$

The current or the present sample gain is denoted as g(k) whereas the g(k-1) is the former or the previous sample gain [16]. Fig.3 shows the encrypted ECG signal &retrieved ECG signal

C. Algorithm to hide the credentials

- Apply Laplacian & Pyramidal filter bank to get two level Contourlet transform.
- Choose the low pass decomposition level to hide the patient's credential
- Encrypt the EPR with RSA algorithm
- Encrypt the biographic signal with ADM
- Covert gray hospital logo to binary
- Choose sequentially the coefficients from low pass band and calculate mod of each coefficient to hide the credentials in least significant bit plane.
- Keep the key base tracking of the coefficients in which the credentials are hidden in the low pass subband.
- Inverse the 2-level CNT to obtain the watermarked image by applying inverse 2-level Contourlet transform.

D. Algotihmic steps to extract the credentials

- Apply Laplacian & Pyramidal filter bank to obtain 2-Level CNT of the image that is watermarked.
- Select the coefficients using key & extract the credentials in reverse way.
- Retrieve the logo, decrypted the text &reconstruct logo using reverse approach.

The next section details the experimental results obtained after implementation of the algorithm using Matlab 2012.

III. EXPERIMENTAL RESULTS

The proposed CNT based approach for multiple watermarking is verified in two image modalities. Images of CT and MRI modalities with each set containing 40 gray images of size 512×512 are considered to examine the performance of the proposed algorithm. ECG samples are from database (MIT-DB). Multiple watermarks like binary hospital logo of size 90×90, ECG signal 2000bytes, & EPR of 260bytes are embedded in an original image utilizing proposed CNT based approach. PSNR&SSIM is calculated for quantitate analysis of proposed algorithm. The performance parameters like Normalized Correlation (NC) and Bit Error Rate (BER) are considered to examine the similarity of original and extracted patient's credentials [16]. PSNR& MSSIM are calculated using eq.(3) and eq.(4) respectively.

$$PSNR = 10.log_{10}\left(\frac{255^2}{\frac{1}{M.M}\sum_{i=1}^{M}\sum_{j=1}^{M}[Q(i,j)-Q'(i,j)]^2}\right) \quad (3)$$

$$MSSIM = \frac{1}{N}\sum_{j=1}^{N_B} SSIM(A_j, A_j') \quad (4)$$

Performance of various other frequency domain techniques, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT) is compared with the proposed CNT based approach. The comparative results are tabulated in Table 1. The CT image modality is considered and text is interleaved using RSA algorithm, whereas ADM approach is utilized for the encryption of ECG of the patient.

Table 1. Comparative results of various transforms on images of CT Modality

Data Hidden	Transform	PSNR	MSSIM
EPR&ECG	CNT	48.06	0.988
	DWT	43.91	0.973
	DCT	40.79	0.957
	DFT	41.51	0.959
EPR,ECG & Logo	**CNT**	**45.97**	**0.982**

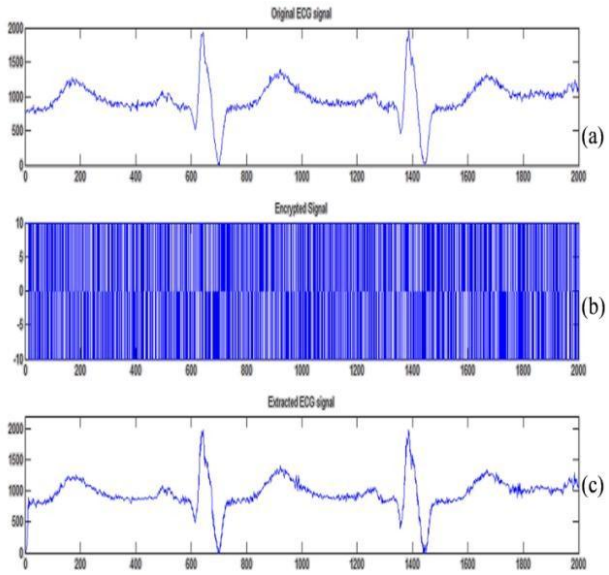


Fig. 3. A medical signal showing ECG of a patient (b) Signal illustrating encryption using ADM (c) Original signal recovered after implementation of step 4.

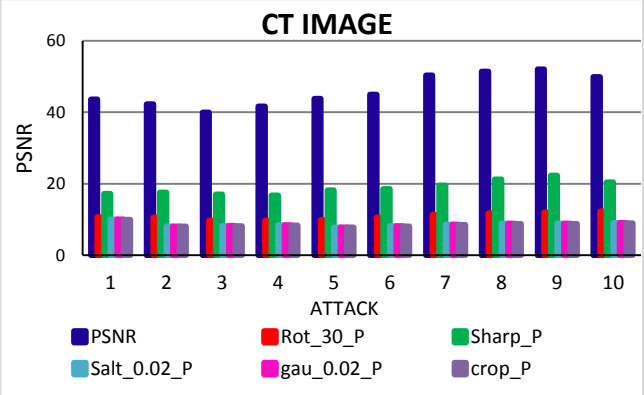


Fig 4: PSNR of CT medical images after rotating, sharpening , cropping Gaussian &salt n paper attack

Table 1 shows that CNT outperforms than the DCT, DFT and DWT as PSNR value obtained is highest than others and SSIM value is near to 1. The original and retrieved ECG signals are similar as their normalized correlation coefficient is 0.9986.Similarly, NC value after extraction of logo is found to 1 .Percentage of error bits , BER of extracted EPR is found to be zero as we get exact recovery of patient's history. The robustness of proposed scheme is also tested by applying different attacks. From table 1 we can see that contourlet transform outperforms than the other transforms as PSNR value is more. Also, by increasing hiding capacity our algorithm claims more imperceptibility based on PSNR and MSSIM values. The algorithm is robust for sharpening and salt and paper noise than rotation and Gaussian noise and results are shown in Fig.4.

IV. CONCLUSION

An efficient technique of interleaving multiple patient credentials using two level contourlet transform has been is implemented for medical image authentication. Comparative study is performed, with other frequency domain techniques which shows that CNT based technique outperforms than others by keeping the same hiding capacity. Also by increasing the hiding credentials CNT gives acceptable PSNR. Similarity index is calculated which is near to one and hence the imperceptibility is preserved. The Robustness is checked using different attacks which claim the technique is robust for salt pepper and Gaussian noise than rotational attack. In comparison with [17, 18] the proposed contourlet based approach gives significant hiding capacity with better PSNR and SSIM values. Many applications like automated Karytopying [19, 20, 21] are gaining importance in HIS and researchers are striving to provide solutions for storage and effective computations. Our future research work plans to further analyze the efficiency of the proposed approach for MFISH imaging in karyotyping.

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