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Protection of Medical Images and Patient Related Information in Healthcare using Chaotic Reversible Watermarking Method

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Abstract— ***The technical revolution associated with the implementation and the development of digital technologies in medicine, has led to the emergence and active development of new directions in many areas of medicine. Confidentiality of Electronic Health Record (EHR) and privacy are two important security requirements for healthcare systems. In today's Internet-connected world, tampering of digital images by malicious users has become very common. This clearly is a direct violation of one's intellectual property rights, and hence, image protection by resolving rightful ownership is gaining utmost importance. Reversible watermarking (RW) techniques are a potential replacement for conventional watermarking systems, in case if the images to be protected are very sensitive. The source and origin of the medical image and patient related information must be authenticated to verify that it corresponds to the right patient. Hence in this work, protection of medical images and patient related information in healthcare using Chaotic reversible watermarking method is presented. The performance of presented method is evaluated in terms of Mean Absolute Error (MAE) PSNR (Peak Signal to Noise ratio), Normalized Cross Correlation (NCC) and RMSE (Root Mean Square Error).***

Keywords— Electronic Health records, medical images, Digital watermarking and Chaotic reversible watermarking Method

I. INTRODUCTION

Modern developments in information and communication technologies have significantly changed medical imaging and information management systems in modern hospitals. Digital storage progressively replaced paper medical images on classic film, and telemedicine systems have enabled the direct exchange of medical images and electronic patient records between qualified doctors around the world [1]. Due to its relevance in clinical diagnosis, treatment, research, and other commercial and non-commercial applications of public and private organizations; medical information is highly valuable and delicate by nature. In recent years the fast and significant advances in terms of information technologies (IT) have generated a large number of changes to conceptual and application-level in to the paradigm of medical information management. The modern and integrated healthcare systems such as Hospital Information System (HIS) and Picture Archiving and Communication System (PACS) among others; provides easy access, manipulation, and distribution of medical data, there are several reasons for the interchange of medical information, e.g. telemedicine applications where we found tele-consultation, tele-diagnosis, and tele-surgery with aims of e-learning of the medical staff [2].

Patient healthcare data which was used to create Electronic Health Record (EHR) for each patient. EHR, including medical images, Electronic Patient Record (EPR), etc., plays an important role in the diagnosis process of a patient. Thus, any manipulation and tampering in such reports may cause fatal diagnosis to the patient. EHR are exchanged among hospitals, doctors, and insurance companies; therefore, preserving the confidentiality of EHR and privacy of patients are the most important security requirements.

On the other hand the Electronic Patient Record (EPR) has replaced the in effective paradigm of the medical record in hardcopy format. Usually, EPR contains diagnosis reports, medical images, and biomedical signals, among other information, however, also could contain medical record such as demographic data, results of medical testing, treatments, medical prescriptions, among others, which are by definition highly confidential. These advances in the technology of medical information management have brought as a consequence new risk by the inappropriate use of the medical information, given the facility with which the digital data could be manipulated and distributed [3]. Security and privacy of medical information are mostly presented as major issue in Healthcare services.

The alliance of digital watermarking and cryptography is the best application for protecting the medical data against misuse and illegal distribution. The digital watermarking is an important way for ownership proof, content protection and authentication of medical information. Digital watermarking is one of the prevalent techniques to protect the ownership of images. However, the performance of watermarking schemes is constrained by their robustness, imperceptibility, and embedding capacity.

Digital image watermarking is a significant advancement of technology in recent years for identifying ownership information of copyright holders and providing multimedia security. This technology embeds the watermark data into a multimedia product (such as text, image, audio, and video)

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and later extracts or detects it from the watermarked product to assert the products. Thus, the host data are protected by inserting the watermark data that cannot be removed or replaced by an eavesdropper [4]. A medical image watermarking scheme must be distortion-free because any small distortion can lead to misdiagnosis and threaten the patient's life. As medical images are highly sensitive to visual quality, most of the copyright protection algorithms use reversible embedding strategies.

Reversible watermarking is an important branch of information hiding technology. This is of great significance for copyright protection and preventing tampering and forgery of digital carrier data (such as audio, image, video, software, etc.). Among them, the watermarks of audio, image and video are achieved by adding or reducing data in the carrier. The software watermark needs to be combined with an algorithm to hide information in the algorithm to ensure that the software is not tampered with or forged [5].

Currently, encryption and watermarking approaches are used to provide authenticity and confidentiality of medical record. The watermarked media being transmitted might get some unwanted channel noises or get attacked upon. This makes the technique less robust resulting in receiving distorted media [6]. Hence in this work, protection of medical images and patient related information in healthcare using chaotic reversible watermarking method is presented.

II. LITERATURE SURVEY

Fatima Abbasi, Nisar Ahmed Memon et. al., [7] presents Reversible Watermarking for the Security of Medical Image Databases. A medical image watermarking system has been proposed which first segments the input medical image into a region of interest (ROI) and region of non interest (RONI) areas. Later it implants two different watermarks in ROI and RONI. The simulation results reveal that proposed system provides better security of medical images as well addresses both the issues of authenticity and confidentiality.

K. Balasamy, S. Ramakrishnan et. al., [8] suggests An intelligent reversible watermarking system for authenticating medical images using Wavelet and PSO (Particle Swarm Optimization). First medical image is treated with wavelet transformation and another image is treated with tent map and a hash function to further protect the secret watermark. Tent map ensures the sensitivity towards changes in the initial value which, can better protect and encrypt the original watermark. The proposed method is thus able to embed watermark with low distortion, take out the secret information and also recovers the original image. The proposed technique is valuable with respect to robustness, capacity and imperceptibility.

H.R. Lakshmi, B. Surekha and S. Viswanadha Raju et. al., [9] presents Real-time Implementation of Reversible Watermarking. Reversible watermarking (RW) techniques are a potential replacement for conventional watermarking systems, in case if the images to be protected are very sensitive. Performance issues related to the real-time implementation of watermarking systems through various algorithms are also featured. Finally, an extension of real-time implementation of RW approach based on asynchronous architectures is introduced.

Priya S, Santhi B, Swaminathan P, Raja Mohan J et. al.,[10] presents Hybrid Transform Based Reversible Watermarking Technique for Medical Images in Telemedicine Applications. This paper overcomes that difficulty in transform domain by using a novel hybrid reversible watermarking algorithm to increase the embedding capacity. Experimental results for medical images and ordinary images show that the proposed method meets out the requirements of the image watermarking system such as imperceptibility, capacity, reversibility and robustness. The output of the proposed method is superior to the existing methods.

Zhengwei Zhang, LifaWu, Yunyang Yan, Shaozhang Xiao and He Sun et. al., [11] suggests An improved reversible image watermarking algorithm based on difference expansion. First, the watermark information is divided into groups, and the information value of each group is calculated. The experimental results show that the proposed algorithm not only has high embedding rate but also has a high visual quality and can achieve full recovery of the original image. Compared with other algorithms, the algorithm has certain advantages.

Abhilasha Sharma, Amit Kumar Singh, Satya Prakash Ghrera et. al., [12] presents Robust and Secure Multiple Watermarking for Medicalb Images. The proposed method applies the combination of discrete wavelet transform and discrete cosine transforms on the cover medical image for the embedding of image and electronic patient records (EPR) watermark simultaneously. The embedding of multiple watermarks at the same time provides extra level of security and important for the patient identity verification purpose.

Nai-Kuei Chen, Chung-Yen Su, Che-Yang Shih, Yu-Tang Chen et. al., [13] presents Reversible Watermarking for Medical Images Using Histogram Shifting with Location Map Reduction. In this paper, an improved lossless data hiding method with histogram shifting for medical images is proposed. In general, medical images consist of many pure black and white points. Experimental results show that our

method can reduce the size of location map up to 95.04% compared to the previous studies.

R. Surya Prakasa Rao, Dr. P. Rajesh Kumar et. al., [14] suggests An Efficient Genetic Algorithm Based Gray Scale Digital Image watermarking for Improving the Robustness and Imperceptibility. The Proposed Genetic Algorithm based Digital Image watermarking scheme is improved by embedding the watermark in Third Level DWT of original image, after applying Singular Value Decomposition (SVD) to watermark image. The Genetic Algorithm optimization

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technique (GA) is used for best scaling factor (SF) to modify the SVD coefficients of watermark image.

Asna Furqan, Munish Kumar et. al., [15] presents a Study and Analysis of Robust DWT-SVD Domain Based Digital Image Watermarking Technique Using MATLAB. This paper presents a robust and blind digital image watermarking technique to achieve copyright protection. In order to protect copyright material from illegal duplication, various technologies have been developed, like key-based cryptographic technique, digital watermarking etc.

III. PROTECTION OF MEDICAL IMAGES AND PATIENT RELATED INFORMATION IN HEALTHCARE

In this section, protection of medical images and patient related information in healthcare using chaotic reversible watermarking method is presented**.** The block diagram of presented method is shown in Fig. 1.

The images and patient related information (HER) are applied as input to the presented method. Integer based wavelet transform is used in the proposed reversible watermarking for lossless recovery of the original medical image. IWT transform divides the cover medical image into low frequency (LL) and high frequency (LH, HL, and HH) sub bands. The Discrete Gould transform (DGT) is used for an image processing application. Each sub band is divided into a number of blocks. For each block, DGT is applied. Then the hybrid transformed image is considered for embedding the medical image and information.

DGT calculates the difference, between the neighboring pixels. Based on Gould's class of inverse relations, DGT for an image is defined as

$$G_{u,v} = (-1)^{u+v}\binom{p}{u-v} \quad (1)$$

For u, v =0, 1, …N-1 and p is the positive Integer

$$\binom{p}{u-v} = \frac{p!}{(u-v)!\,(p-u+v)!} \quad (2)$$

The DGT consists of a constant unit in lower triangular matrix to detect the image edges. With N=2 and p=1 for an image S is defined as

$$G = \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix} \quad (3)$$

Applying G to s the transformed image S as

$$s^1 = GSG^t \quad (4)$$

The DGT is applied to the integer wavelet coefficient of the medical image for reversible image watermarking. Using the proposed method, medical image is embedded in top left corner pixel. In the presented method, first the IWT is applied to the original medical image. High frequency sub bands (LH, HL, HH and LL) are considered. Each sub band is divided into a number of blocks. For each block, DGT is applied. Then the hybrid transformed image is considered for embedding the medical image and patient information.

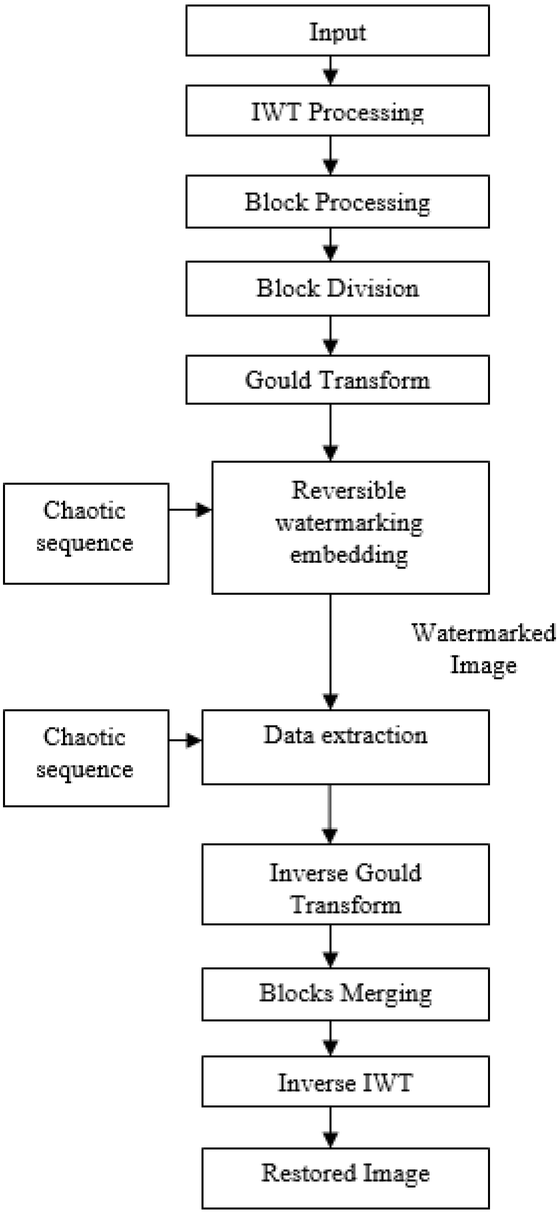

Fig. 1: BLOCK DIAGRAM OF PRESENTED WATERMARKING METHOD

Gould transform size is based on the non- overlapping block size. Consider a block (S^t) of size 2X2 in HL sub band of the IWT transformed image,

$$S^t = \begin{bmatrix} S_1 & S_2 \\ S_3 & S_4 \end{bmatrix} \quad (6)$$

And transform of an image block is defined as

$$S_1' = S_1; S_2' = S_2 - S_1; S_3' = S_3 -; S_4' = S_4 + S_1 - (S2 + S3) \quad (7)$$

Apply GT to S^t block to generate a S^{tg}

$$S^{tg} = \begin{bmatrix} S_1' & S_2' \\ S_3' & S_4' \end{bmatrix} \quad (8)$$

the DGT Watermark information is embedded in each block by modifying the pixel at (L, L) position. In discrete Gould transform and inverse DGT there are no changes in block first pixel, at position (1, 1). It retains the original value and pixel S_4' is not used in any other pixel within the block. If there is any change in S_4'pixel in one block, then it will not affect other pixels in that block. Watermark bit (w) is embedded in S_4'. Also, the old pixel values in $S_4'$is need not to be maintained for lossless recovery of the original medical image at the extraction side. Because the pixel value in S_1 is not changed after applying the GT. Using S_1 pixel, the old pixel value in S_4' is retrieved.

To generate a chaotic sequence (CS), a key is needed. Concatenation of LS map parameters, x_0 and r, creates the key. Using this key, a chaotic sequence is generated, and the initial value effect can be faded by generating a sequence with a length three times bigger than that needed and picking the last segment. This sequence is used for encrypting medical image and patient information. The order of choosing sub bands and pixels of each sub band as host positions is based on the chaotic sequence. This leads to high confusion and diffusion which are the result of chaotic sequence features that make them appropriate for security aspects.

Chaotic map is a mathematical concept which is equal to evolution function. 'ese functions are extremely sensitive to their initial conditions and exhibit chaotic behavior that means a small change in input parameter leads to an unpredictable change in output. Logistic-Sine map (LS) is introduced as an intensive chaotic map defined as follows:

$$x_{n+1} = \left(r.x_n(1 - x_n) + \frac{(4 - r)\sin(\pi x_n)}{4} \right)$$

$$\text{mod1r} \in (0,4]; \quad x_n \in [0,1] \ (5)$$

In this work Reversible watermarking technique is used without any additional key information also reconstruct the original image 100%. The original pixel $S_4'$is identified using equation 8 for embedding the watermark information.

$$S_2' + S_3' = S_2 + S_3 - 2S_1 \ (9)$$

By substituting equation 9 in equation 8,

$$S_4' = S_4 + S_1 - (S_2' + S_3' + 2S_1)(10)$$

$$S_4 = S_4' + S_2' + S_3' + S_1 \ (11)$$

Multiply S_4 by two for embedding the watermark bit (Wk)

$$NS_4 = 2 * S_4 + wk \ (12)$$

Substitute NS_4 in Eq-10 instead of S_4

$$S_4' = NS_4 + S_1 - (S_1' + S_3' + 2S_1 \ (13)$$

$$S_4' = NS_4 - (S_2' + S_3' + S_1) \ (14)$$

Now, substitute S_4' in Eq 8 to generate hybrid transformed block S^{tg}. This watermark embedding process is repeated for embedding all the watermark bits and a hybrid transformed watermarked image is generated.

On the receiver side, at first, electronic healthcare records data is extracted from the watermarked image and then the integrity checking is done to ensure whether the watermarked image has been tampered or not. At the receiver side, Inverse integer wavelet transform and inverse Gould transform is applied to the watermarked image to extract the original data. The S_4' is identified using equations 7 and 8. The embedded bit is extracted from the last position using modulo-division. The watermark bit extraction is given as

$$W = mod(NS_4', 2) \ (15)$$

After the watermark bit is extracted, the original medical image must be reconstructed without any loss by not requiring any additional information for further processing. For each block, the original pixel S_4' is identified at the receiver side using equation 9 to 11. From the modified watermarked pixel NS_4', the extracted bit (W) is removed. Then the final pixel value is divided by two in order to get the original pixel S_4 value.

$$S_4' = NS_4' - W \ (16)$$

$$S_4' = \frac{H}{2} (17)$$

After getting the exact transformed pixel, inverse discrete Gould transform is applied. The inverse GT is defined as

$$S = G^{-1} S' (G^T)^{-1} \ (18)$$

$$S = \left[\begin{pmatrix} S_1' & S_2' + S_1' \\ S_3' + S_1' & S_1' + S_2' + S_3' + S_4' \end{pmatrix} \right] \ (19)$$

The sub band images are combined through block merging. Inverse IWT is applied for getting the original medical image. The restored medical image is 100% equal to the original medical image.

IV. RESULT ANAYSIS

In this section, protection of medical image and patient related information in healthcare using chaotic reversible watermarking method is implemented. The result analysis of presented method is demonstrated here. To protect the medical image and patient related information, the image is watermarked and at receiver the watermarked image reconstructed. The Fig.2 shows the patient medical images and their watermarked and restored images.

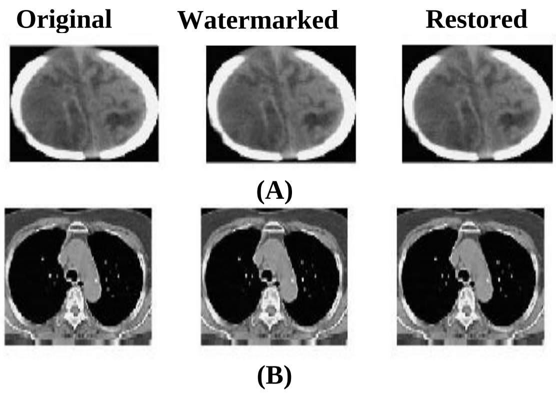

Fig. 2: (A) BRAIN AND (B) CHEST WITH ITS WATERMARKED AND RESTORED IMAGES

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The performance of the proposed method is measured using the following image quality measures. In all the measures original image is referred as *X* and watermarked image is referred as *X* ', pixel position is referred as (p,q) in an image of size (mXn). The performance of presented method is measured in terms of Mean Absolute Error (MAE) PSNR (Peak Signal to Noise ratio), Normalized Cross Correlation (NCC) and RMSE (Root Mean Square Error).

Mean Absolute Error (MAE): It is referred as the average of the absolute difference between the two images and defined as

$$MAE = \frac{1}{mn}\sum_{p=0}^{m-1}\sum_{q=0}^{n-1}|X(p,q) - X'(p,q)| \quad (20)$$

MAE value is equal to zero, then there is no loss in the watermarked or extracted image compared to the original image.

Peak Signal to Noise Ratio (PSNR): It is a basic measure used to identify the image quality with the distorted image. For the proposed method, between Original medical and watermarked medical image the PSNR value is calculated. High PSNR value leads to low distortion and good image quality. The PSNR is expressed as

$$PSNR = 10log_{10}\left(\frac{255^2}{MSE}\right) \quad (21)$$

Where MSE is the mean squared error between original and watermarked image, it is defined as

$$MSE = \frac{\sum_{p=0}^{m-1}\sum_{q=0}^{n-1}(X(p,q) - X'(p,q))^2}{mXn} \quad (22)$$

Root Mean Squared Error (RMSE): It is defined by the previous equation that is rooted value of the MSE

$$RMSE = \sqrt{MSE} \quad (23)$$

If RMSE value is zero, then distorted image is equal to the original image. This measure is mainly used to measure the reversibility of the watermarking scheme.

Normalized Cross Correlation (NCC): NCC is the measure of correlation between two images. It gives the similarity value between the two images. If NCC value is equal to one, then both the images are same. NCC value lies between 0 and 1.

$$NCC = \frac{\sum_{p=0}^{m-1}\sum_{q=0}^{n-1}X(p,q)X'(p,q)}{\sum_{p=0}^{m-1}\sum_{q=0}^{n-1}X'(p,q)^2} \quad (24)$$

Table 1: PERFORMANCE METRICS EVOLUTION

Performance metrics	Traditional health care data protection methods	Chaotic Reversible Watermarking Method (RWM)
MAE	3.02	0.0005
NCC	0.45	1
PSNR	42.34	89.76
RMSE	2.34	0.0004

The Fig. 3 shows the PSNR comparison between traditional healthcare data protection methods and presented reversible watermarking method.

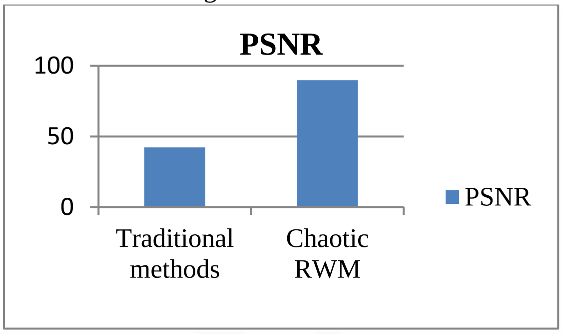

Fig. 3: PSNR COMPARATIVE GRAPH

Therefore, presented reversible watermarking method protects the medical image and patient information. This method has better performance in terms of PSNR, NCC, MAE and RMSE.

V. CONCLUSION

In this work, protection of medical images and patient related information in healthcare using chaotic reversible watermarking method is presented. First the HER data is applied to IWT forlossless recovery of the original medical image. By applying IWT to protect medical image, presented method obtains the high frequency sub-bands. In these sub bands, non-overlapping blocks are identified and DGT is applied to the medical image's integer wavelet coefficients for reversible image watermarking. EHR firstly is encrypted by a chaotic sequence and then embedded in to a cover image. The reversible watermarking embeds the secret data within a medical image in a lossless manner. At the receiver side, the original medical image and the watermark information are extracted as it is in the sender side. This extraction process need not require any additional information. The performance of presented method is measured in terms of PSNR, MAE, NCC and RMSE. The performance of presented system is compared with traditional healthcare data protection methods. The presented method has effectively protected the medical image and information of patient.

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