DOI 10.29042/2018-3206-3214

Helix Vol. 8(2): 3206-3214

A Robust Dual Watermarking Technique for Medical Images in E-Healthcare Records

***1Lendale Venkateswarlu, 2N Vyagreswara Rao, 3B Eswara Reddy**

*1Research Scholar, JNTUA, Anantapuram, CMR College of Engg. & Tech., Medchal (Dist). , TG, India.

2Department of CSE, CVR College of Engineering, Ibrahimpatan, R.R. Dist., TG, India.

3Department of CSE, JNTUA College of Engineering, Kalikiri, Chittoor Dist., AP, India

Email: **1venkatlendale@gmail.com, 2 nvr@ieee.org, 3eswarcsejntua@gmail.com*

Received: 20th November 2017, accepted: 02nd December 2017, Published: 28th February 2018

Abstract

This paper proposes a prudent implementation of robust pipeline in the domain of watermark based secure medical image transmission. The pipeline comprises of three stages, involving insertion of first watermark in the first stage and the second watermark in the second stage. Insertion of the watermark invokes a multi transform algorithm implemented in two steps. The first step is the application of Two-Way Arnold Transformation (TWAT) which scrambles the pixel locations in the source image, based on the number of cycles passed as one of the arguments to it, leading to a reduction in spatial correlation. The second step is 2-D Wavelet Transformation (WT) applied to the scrambled pixels that exploit the reduced correlation feature to generate the large values of coefficients. These large coefficient values can efficiently accommodate the wavelets coefficients of the inserted watermark. This step is a novel contribution compared to the existing models. Subsequently, the inverse WT is applied which concludes the first stage of the pipeline. The second stage of the pipeline also implements the same sequence of steps as that of the first stage but with the second watermark. In the final stage of the pipeline, the inverse TWAT is applied twice the number of times to the forward transformations applied in the first two stages. The entire pipeline is termed as Multi Transform based Robust Dual Water Marking (MTRDW). The pipeline is implemented on benchmark images with patient information and hospital logo as watermarks. The claimed features of the model are presented through computing the quality metrics such as SSIM, NCC and PSNR from the experiments conducted.

Keywords*:* DWT, Integrity, Medical Imaging, PSNR, SSIM, TWAT, Watermarking

Introduction

The Information technology applications in biomedicine are combined with the hospital environment medical data resulting into online dispensary which is also known as telemedicine [1]. As a natural consequence, maintaining the confidentiality, integrity and robustness of data on the Internet against the various malicious attacks has become a complex task [2-4]. In the scenario of Networked Hospitals [5-11], exchanging medical information among the hospitals is a common phenomenon. Medical information (informatics) is generally presented in the form of images [12-13]. Medical Imaging is a process of creating images of the parts of the human body for the purposes of prognostic diagnosis purpose [14]. Medical imaging techniques such as endoscopy, cardiology, radiology, ultrasound scan etc. are used to study the functioning of various parts of the human body.

Telemedicine and image processing reduce the difficulty involved in exchanging medical images among hospitals manually. But, the distribution of medical information over the Internet poses a threat of illegal use of the information. Therefore, the security of medical image is a prime goal of medical image processing. Digital watermarking [15-16] techniques are used for providing the security [17] to any medical image which is commonly referred to as the cover image. Digital watermarking is a process of embedding some extra piece of information (watermark) which can be easily retrieved and compared with the original information to assess the authenticity of information. This technique is widely used for adding authentication information and provides additional security without affecting the contents of the cover image. Many researchers have proposed various digital watermarking techniques that are classified based on various parameters such as watermarking domain, type of document on which watermark is applied, human perception (vision and speech) and the applications. Broadly speaking there are two types of watermarking techniques: Visible and Invisible. Visible watermarking techniques render the watermark signal to be clearly visible in the cover image to mark the ownership of the content. The invisible watermarking inserts the watermark in such a way that it is not visible to the human eye. Thus, the invisible watermark is used to provide image authentication and protect the image from being duplicated. According to the literature, digital watermarking techniques should possess the following properties:

Transparency - The inserted watermark should not reduce the quality of the cover image.
Robustness - The watermark should be designed in such a way that, it is unaffected by all attacks.
Capacity - Capacity defines the maximum amount of data that can be inserted into image without degrading the cover image.
Fidelity - Fidelity refers to the similarity of original and watermarked images. Watermarking should not

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introduce visible distortions as it reduces the correctness of the data.

Security - Secret key must be used for embedding and detection process [18-22].

While inserting the watermark, care must be taken so that watermark is embedded in the proper Region of Non-Interest (RONI) [23-24]. Otherwise, crucial information pertaining to the patient may be lost [25-30]. Any information pertaining to a patient such as patient identity as watermark helps in preserving the integrity of data related to a specific patient. Many researchers have proposed watermarking techniques but very few have attempted in dual watermarking as it involves fidelity of the image. The first double watermarking technique was proposed by Wen-Nung Lie in 2003[50]. Subsequently, Bo Chen [51] proposed a dual robust fragile watermarking technique. Li Jing and W. X. Wang proposed dual zero watermarking [52-53]. Very few researchers have proposed a double watermarking technique in medical images. Keeping all these aspects in view, a robust dual copyright watermarking technique is developed and presented in this paper.

Section 2 describes the basic theory of the two transformations used in the technique; Section 3 contains the details of the method employed. Results and analysis are described in detail in section 4.

Fundamental Theory of Transforms

The two transformations used in the proposed watermarking techniques are

1. Two-way Arnold transformation
2. Discrete Wavelet transformation.

Two -Way Arnold transformation

In the literature of image scrambling techniques, there are many innovative algorithms to scramble an image [31-32]. Two-Way Arnold Transformation (TWAT) algorithm [33-35] is a recent development in scrambling techniques, which scrambles the image in two directions at the same time. If we take an image NxN with (x, y) as original pixel coordinates then new coordinates (X', Y') are obtained by the following transformation.

$$\begin{bmatrix} X' \\ Y' \end{bmatrix} = \begin{bmatrix} 2 & 3 \\ 3 & 5 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} MOD\ (N) \quad \text{Where } x, y \in \{1\ldots\ldots N\}.$$

This transformation contributes to the distribution of pixels of medical images uniformly that affects the brightness of the image. But the inverse of this transformation makes it possible to restore the image to its original state.

Application of TWAT once to the original image is considered as one cycle. If it is applied twice, then it is called two cycles. Every application of TWAT to the Arnold transformed image brings the more uniform distribution of pixels in the image. In Fig.1 Two Way Arnold Transformation of chest Image is shown. Decryption of n-cycle TWAT Image requires the application of Inverse Two Way Arnold Transformation (ITWAT) n-times.

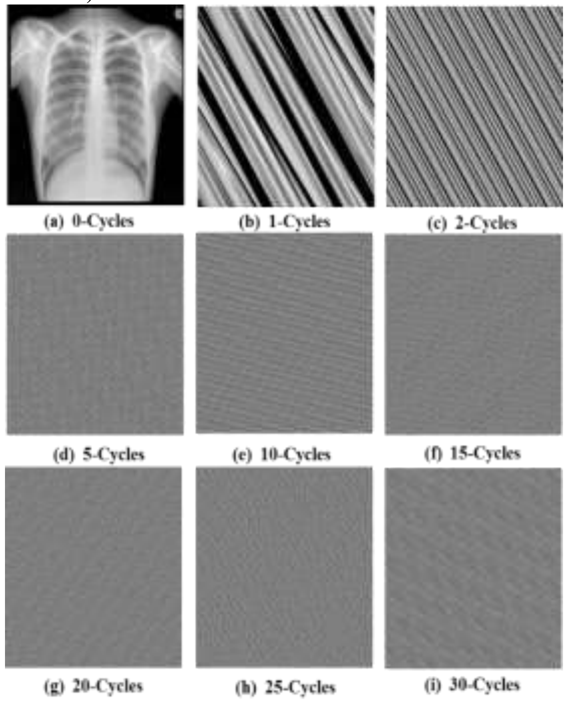

Fig. 1 (a) - (i): Resultant Images after applying Two-way Arnold Transformation with Varying Cycles.

Discrete Wavelet Transformation

The Discrete wavelet transformation (DWT) of the original image produces four sub-band images [36]. A cover image, say I, can be represented by a 2-Dimensional array I[m, n] with m rows and n columns where m, n are positive integers. DWT is first applied on m rows of the cover image to get low-frequency (L) and high-frequency (H) bands. Information about the edges is present in high-frequency, whereas the low-frequency bands are again split into low-frequency and high-frequency sub-bands. Since the human eye is less sensitive to visua

lize the change in edges, the high-frequency components are used in watermarking. DWT can be applied row and column wise to get DWT coefficients such as LL1, HL1, LH1, and HH1. They are also known as sub-bands as shown in Fig. 2. LL1 sub-band can be further subdivided into four more sub-bands as shown in the Fig. 2...

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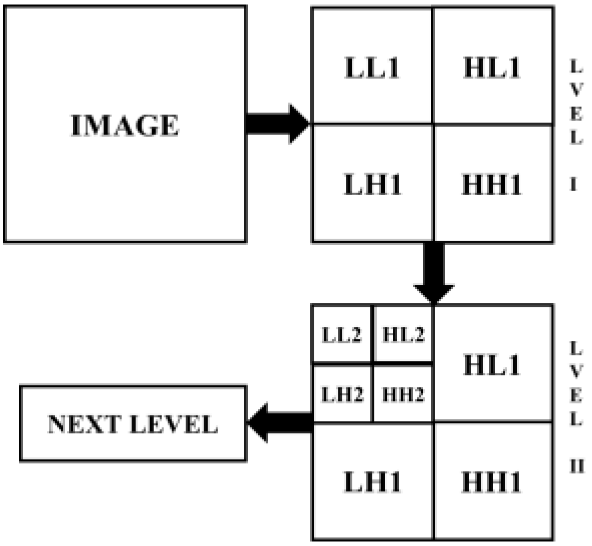

Fig. 2: Two-level Wavelet Transform

This process of subdivision can be continued to the required number of levels. The frequency sub-band LH contains the vertical information of the cover image, HL contains the horizontal information of the cover image and the HH sub-band contains the diagonal information of the cover image [37-41]. Very often watermark is inserted in LH and HL bands because these bands produce a less distorted watermarked image

Proposed Two Way Arnold and Wavelet Based Robust Dual Watermarking Method

Original Robust dual copyright watermarking [42-48] technique for medical image involves two aspects.

1. Dual watermark insertion
2. Dual watermark extraction

The dual watermarks used for medical images are hospital logo (HLOGO) and patient identification (PID). Dual watermarking is a process of embedding two watermarks for transmission of images in a secure way. Two invisible watermarks (HLOGO, PID) are embedded into a medical image. Generally, these dual watermarks have an advantage of robustly carrying the dual marks relating to the owner. The results are tested with quality metrics such as Structural Similarity Index (SSIM)[49], Normalized Cross Correlations (NCC) and Peak Signal to Noise Ratio (PSNR)

3.1 Dual watermark insertion

Dual watermark insertion algorithm is the stepwise procedure to insert watermarks HLOGO and PID. It invokes the single watermark insertion algorithm twice to insert a watermark. Because the cover image is scrambled two times watermarks do not overlap with each other.

Algorithm: Dual watermark insertion
//Application of N – cycles TWAT on the cover image G *//getting scrambled SG.* SG← TWAT (G, N); *//Insert HLOGO watermark into the SG getting single* *//watermarked scrambled image SWSG.* SWSG←WAT_INSERTION (SG, HLOGO) *//Application of N – cycles TWAT on the SWSG.* SWSG← TWAT (SWSG, N); *//Insert PID watermark into the SWSG for getting dual* *//watermarked scrambled image DWSG.* DWSG←WAT_INSERTION (SWSG, PID) *//Application of 2N – cycles ITWAT on the DWSG to* *//produce the watermarked image WG.* WG ← ITWAT (DWSG, 2 * N);

The single watermark insertion algorithm describes the steps involved in watermark insertion. In this algorithm to insert the watermarks are performed by applying the formula:

$$F(m, n) = f(m, n) + \alpha * W(i, j) \quad \text{..........eq. 1}$$

where $0 < \alpha <= 1$ is a scaling, factor used for embedding watermark. F (m, n) represents scrambled watermarked wavelet coefficients and f(m, n) are the scrambled cover image wavelet coefficients. W (i, j) is the matrix of Wavelets coefficient of the image in the frequency domain.

Algorithm: Single watermark insertion

Procedure WAT_INSERTION (SG, W)
//SG- is scrambled cover image
//W -is watermark image
BEGIN
//Apply DWT on the SG getting four different bands of
//Wavelet coefficients.
[SGLL SGLH SGHL SGHH] ← DWT(SG);
//Apply DWT on the W.
[WLL WLH WHL WHH] ← DWT(W)
//scale down the Wavelet coefficients of W by using
//scaling factor α
[WLL WLH WHL WHH] ← α * [WLL WLH WHL WHH]
//Add the W content in SGLH band.
ADD (SGLH, WLL)
*//Apply inverse DWT on SG** for getting watermarked*
//image WSG.
WSG← IDWT (SGLL, SGLH, SGHL, SGHH)
END.

A step by step process for dual watermarking insertion is shown in Fig. 3.

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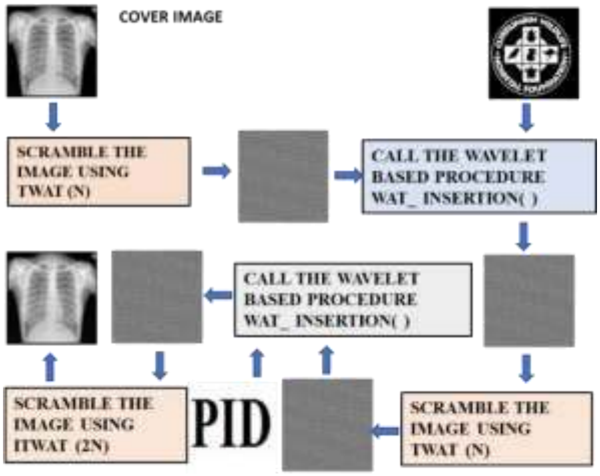

Fig. 3: Dual Watermark insertion

Dual Watermark extraction

In the watermark extraction technique, the watermarked image is first scrambled by applying the TWAT. Watermarked image and the original cover image are split into same N levels that were done for embedding the watermark. For retrieving the watermark, the original image should be known for extraction. This kind of a watermarking technique calls Non-Blind watermarking technique. The extraction procedure is given by:

W (i, k) = (FR (m, n)- f (m, n))/α; …….. eq. 2

Where FR (m, n) are DWT coefficients of received watermarked image, f (m, n) is the DWT coefficients of the original cover image after scrambling using TWAT. α is a scaling factor applied to the insertion of a dual watermark. As noise may be added to the image by attacks or transmission over the public or private network channel to communicate, the extracted sequence may contain both positive and the negative values due to noise present in the communication channel.

A step by step procedure for dual watermark extraction is shown in Fig.4

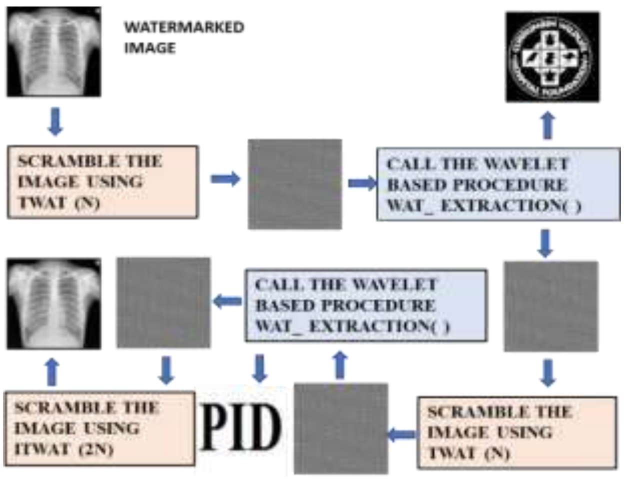

Fig. 4: Watermarking Extraction

The same is given as an algorithm consisting of the following steps to retrieve the dual watermark.

Algorithm: Dual watermark extraction
//Apply of N – cycles TWAT on the cover image G and //watermarked image WG getting scrambled SG and SWG SG← TWAT (G, N); SWG← TWAT (WG, N); *// Extract the RHLOGO watermark from the SWG and SG* RHLOGO ← WAT_EXTRACT (SWG, SG) *//Application of N – cycles TWAT on the SWG and SG.* SG← TWAT (SG, N); SWG← TWAT (SWG, N); *// Extract the RPID watermark from the SWG and SG* RPID ← WAT_EXTRACT (SWG, SG) *//Validate with the retrieved watermarks RHLOGO and //RPID.*

Dual watermark extraction algorithm explains step by step procedure to retrieve the two watermarks. It calls the single watermark extraction algorithm two times to retrieve the watermarks.

Algorithm: Single watermark extraction
Procedure WAT_EXTRACTION (WSG, SG) *//SG, WSG- is scrambled cover image and watermarked //image* BEGIN *//Apply DWT on the SG and WSG getting four different //bands of Wavelet coefficients.* [WSGLL WSGLH WSGHL WSGHH] ← DWT(WSG); [SGLL SGLH SGHL SGHH] ← DWT(SG); *//Retrieve the WLL content in SGLH band.* RETRIVE (SGLH, WLL…) *//scale up the Wavelet coefficients of WLL … by using //scaling factor α* [WLL WLH WHL WHH] ← [WLL WLH WHL WHH] / *α* *//Apply inverse DWT on WLL… for getting watermark //image W.* W← IDWT (WLL…) END.

Experimental Results

The proposed algorithm is simulated using MATLAB code with forty-five medical cover images (size 512X512) and nine watermark images (size 128 X 128) as input. First, the cover image is a medical image and is scrambled by applying TWAT instead of directly

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applying DWT. To insert watermarks, TWAT is applied with varying iterations to scramble the medical image.

The dual watermarking technique is simulated with various attacks like noise (Gaussian Noise), compression (Jpeg Compression) and cropping (Geometric Cropping along left, right, Down and up) using MATLAB. For demonstrating the work two medical images are considered. Fig.5 (a) chest X-Ray and Fig.5 (b) cross-sectional image of a human skull is the original cover images.

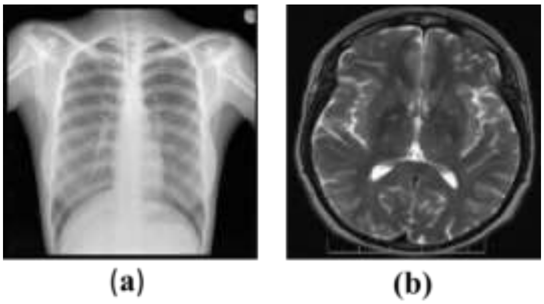

Fig. 5: Cover images (a) chest X-Ray and (b) Cross-Sectional Image of a human skull.

Fig. 6 (a) and 6(b) are the resultant images after applying the TWAT to the two cover images eleven times.

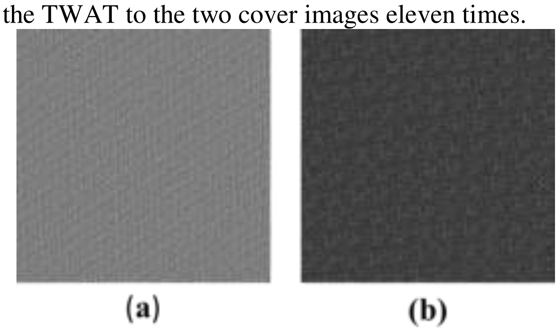

Fig. 6: Transformed cover images: (a) chest X-Ray and (b) Cross-Sectional Image of human skull

The Fig.7 (a) & 7(b) are the dual watermarked images of chest x-ray and CT-scan respectively. It is observed that perceptually cover images in Fig. 5 and watermarked images in Fig.7 are identical. Therefore, it is concluded that inserting a watermark on images does not perceptually deteriorate original image, which is a necessary condition for medical images. Experimental results show high PSNR values for watermarked images and extracted watermarks.

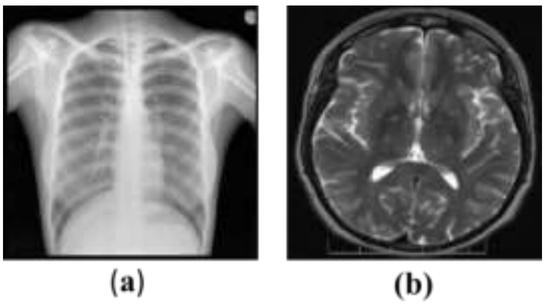

Fig. 7 (a) and (b) Dual watermarked images

Images in Fig.8 show the watermark images and their respective extracted images before attacks which demonstrates that the watermarks are perceptually identical.

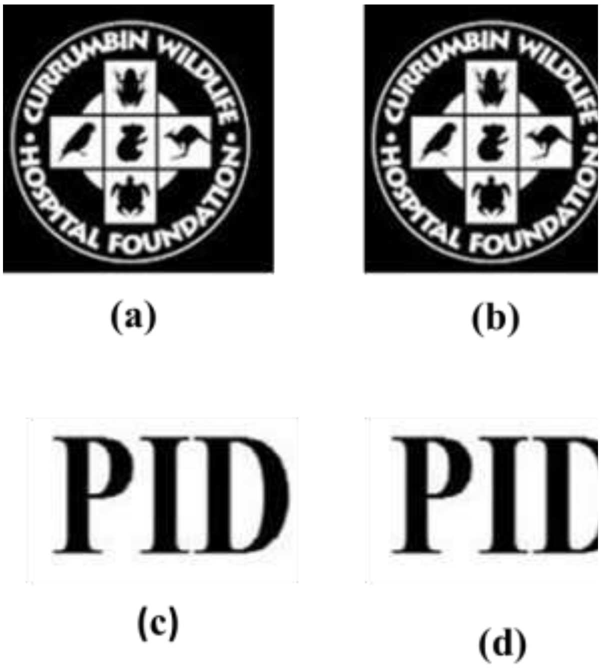

Fig. 8 (a) and (c) original watermarks, (b) and (d) extracted watermarks

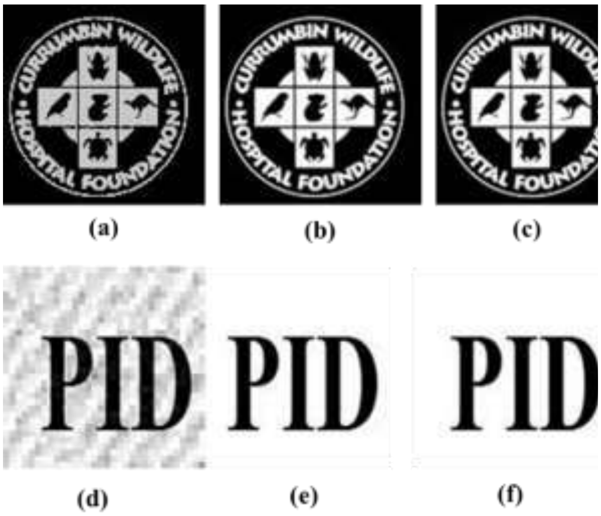

Fig. 9 Extracted Watermarks after attacks.

Figs 9(a) and 9(d) show the images extracted after the Gaussian attack with a variance of 0.0001. Figs 9(b) and 9(e) shows the images extracted after 10% Compression attack, Fig 9(c) and 9(f) are the images extracted after 2% (x and y axis) cropping attack

Tables I, II…VIII shows the experimental results for the images in terms of metrics for the quality of images with various scales. The metrics considered are Peak Signal Noise Ratio (**PSNR**) structural similarity (**SSIM**) index and Normalized Cross Correlation (**NCC**).

Table I Shows quality metrics of X-Ray and CT-Scan images before and after various attacks (Gaussian,

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Compression and Cropping attacks). From the values, it is clear that as watermark content increases the quality of cover image decreases. But this decrease is not hampering perceptual visibility of the cover image.

TABLE I watermarked images with varying scaling factors

Cover image	Watermarked image				
	Metrics	*α= 0.01*	*α = 0.05*	*α = 0.1*	*α = 0.15*
X-Ray	PSNR	54	42	36	32
	SSIM	1.0	0.96	0.856	0.733
	NCC	1.0021	1.0025	1.0028	1.0030
CT-Scan	PSNR	54	41	35	32
	SSIM	0.997	0.954	0.862	0.765
	NCC	1.0022	1.0025	1.0027	1.0027

Table II shows the values of PSNR, SSIM and NCC after extracting the watermark from the image. It contains quality metrics for extracted watermarks with different scaling factors. The values in tables show that the inserted and extracted watermarks are almost identical which is evident from high PSNR values for the watermark.

TABLE II Extracted watermark with varying scaling factors

Watermark image	Extracted Watermark				
	metrics	*α= 0.01*	*α = 0.05*	*α = 0.1*	*α = 0.15*
HLOGO	PSNR	H	H	H	H
	SSIM	1	1	1	1
	NCC	1.001	1.001	1.001	1.001
PID	PSNR	H	H	H	H
	SSIM	1	1	1	1
	NCC	1.001	1.001	1.001	1.001

Table III shows the values of quality metrics when the watermarked image is subjected to Gaussian noise attack with variance 0.0001, 0.0005, 0.001 and 0.0015 when the scaling factor is fixed as 0.1. It is evident from tables that quality parameters (PSNR, SSIM and NCC) drastically decreased when watermarked image is subjected to Gaussian attack.

TABLE III Gaussian noise attack on watermarked image with varying variance

Cover image	Watermarked image fixed with Scaling factor 0.1				
	metrics	*σ^2 = 0.0001*	*σ^2 = 0.0005*	*σ^2 = 0.001*	*σ^2 = 0.0015*
X-RAY	PSNR	28	26	20.4	20.4
	SSIM	0.287	0.286	0.285	0.286
	NCC	1.0024	1.0031	1.0034	1.0037
CT-SCAN	PSNR	20.4	20.4	20.4	20.4
	SSIM	0.218	0.216	0.218	0.216
	NCC	1.0025	1.0032	1.0035	1.0039

Table IV shows quality metrics of extracted watermark images HLOGO and PID with variance 0.0001, 0.0005, 0.001 and 0.0015 when the scaling factor is fixed as 0.1. The results are encouraging in terms of robustness and quality of the watermark images against Gaussian noise attack.

TABLE IV Extracted watermark when Gaussian noise attack applied on watermarked image

Watermark image	Extracted watermark fixed with scaling 0.1				
	metrics	*σ^2 = .0001*	*σ^2 = 0.0005*	*σ^2 = 0.001*	*σ^2 = 0.0015*
HLOGO	PSNR	20.5	19.4	20.2	19.5
	SSIM	0.898	0.873	0.874	0.89
	NCC	0.892	0.881	0.879	0.875
PID	PSNR	19.5	18.2	18.6	18.6
	SSIM	0.732	0.675	0.634	0.625
	NCC	0.870	0.866	0.872	0.861

Table V shows quality metrics when compression attack is applied on the watermarked image. The percentage of compression is taken as 5, 10, 15 and 20. It is evident from the values that quality parameters are decreased when watermarked image is subjected to Jpeg compression attack.

TABLE V Watermarked image with Jpeg Compression attack is applied

Cover image	Watermarked image with compression is applied				
	metrics	*Comp= 5%*	*Comp= 10%*	*Comp= 15%*	*Comp= 20%*
X-RAY	PSNR	33.9	33.9	34.5	34.9
	SSIM	0.819	0.822	0.842	0.853
	NCC	0.977	0.977	0.978	0.979
CT-SCAN	PSNR	33.7	34.1	35.4	36.4
	SSIM	0.846	0.858	0.890	0.910
	NCC	0.980	0.980	0.982	0.983

Table VI shows quality metrics of extracted watermark images HLOGO and PID when Jpeg compression attack with the percentage of compression taken as 5, 10, 15 and 20 is applied. The results are encouraging in terms of robustness and quality of the watermark images against the attack.

TABLE VI Extracted watermark when Jpeg compression attack applied on watermarked image

Watermark image	Extracted Watermark with compression is applied				
	metrics	*Comp 5%*	*Comp 10%*	*Comp 15%*	*Comp 20%*
HLOGO	PSNR	H	H	25.0	20.7
	SSIM	1.0	1.0	0.970	0.894
	NCC	0.8661	0.792	0.759	0.716
PID	PSNR	H	H	22.8	15.8
	SSIM	1.0	1.0	0.631	0.548
	NCC	0.8671	0.794	0.759	0.712

TABLE VII cropping attack on watermarked image

Cover image	Watermarked image fixed with scaling factor0.1				
	metrics	*Left 10%*	*Right 10%*	*Top 10%*	*Bottom 10%*
X-RAY	PSNR	40	41	40	41
	SSIM	0.89	0.89	0.89	0.89
	NCC	1.0014	1.0014	1.0014	1.0014
CT-SCAN	PSNR	40	41	41	41
	SSIM	0.89	0.89	0.89	0.89
	NCC	1.0014	1.0014	1.0014	1.0014

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Table VII shows the values of quality metrics when the watermarked image is subjected to cropping attack with left, right, top and bottom when the scaling factor is fixed as 0.1. It is evident from tables that quality parameters (PSNR, SSIM and NCC) decreased when watermarked image is subjected to the attack.

Table VIII shows quality metrics of extracted watermark images HLOGO and PID when cropping 10 percentage on left, right, top and bottom when the scaling factor is fixed as 0.1 is applied. The results are encouraging in terms of robustness and quality of the watermark images against the attack.

TABLE VIII Extracted watermark when cropping attack applied on watermarked image

Watermark image	Extracted watermark fixed with scaling factor 0.1				
	metrics	*Left 10%*	*Right 10%*	*Top 10%*	*Bottom 10%*
HLOGO	PSNR	20	20	20	20
	SSIM	0.86	0.86	0.86	0.86
	NCC	0.901	0.901	0.901	0.901
PID	PSNR	20	20	20	20
	SSIM	0.86	0.86	0.86	0.86
	NCC	0.901	0.901	0.901	0.901

Conclusion

The present work describes the concept of dual watermarking. The cover medical image was dual watermarked maintaining high robustness. The two different types of invisible watermarks used were the robust watermarks HLOGO and PID. The process started by applying TWAT to medical images followed by DWT and their inverse. The major part of the work involves the insertion and extraction of invisible watermarks and the outputs were tested by applying different attacks to the output images. The experimental results show the good quality watermarked images. And when attacks are applied, retrieved watermarks were not remarkably degraded. The above findings are evident from the values of the image metrics PSNR, SSIM and NCC.

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