



Hybrid Transforms Based Watermarking Algorithm for Multi-Modal Medical Imaging Modality Applications

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Abstract

In recent years, telemedicine, tele-radiology, tele-consultation, tele-diagnosis and telematics services are playing a key role in the growth of medical applications. Medical information transmission has increased with the use of telemedicine. But security of patient information is the main issue when transmitted over digital multimedia. Security for the patient data can be provided by using watermarking technique. This work concentrates on the development of transform based non-blind hybrid watermarking methods, combining three and four transforms such as Discrete Wavelet Transform (DWT), Contourlet Transform (CT), Discrete Cosine Transforms (DCT) and Singular Value Decomposition (SVD). The proposed methods are compared with the respective existing methods in terms of performance indices such as reliability, robustness and imperceptibility. The results show that these methods are more secure, reliable and robust. They are validated/benchmarked by applying the attacks such as filtering, cropping, compression and noise. The validated algorithms are used for ensuring the authenticity of medical imaging modalities such as X-Ray, CT, MRI and Ultrasound of various organs such as lungs, brain and spine etc.

Currently, keeping patients records in confidence was the sole responsibility of the Physicians. This means that the Physicians shall not disclose any medical information related to the patients or discovered by

the physician in connection with the treatment of a patient to any unauthorized person. However, with the advances in recent computer technology, and its permeance into the medical field through E-health and telemedicine creating many challenges about confidentiality of data in storage and transmission. Transferring medical data such as radiological scans from a medical database center to another one without applying any security techniques leads to low level of privacy for the patients. Hence telemedicine is an important aspect, enables consultations by remote specialists, loss-free and immediate availability of individual patient information, and improved communication between the partners of a health care system. Radiological imaging modalities such as CT, MRI, X-ray and ultrasound are playing a prominent role in the diagnosis of many diseases. In this work proposed combination of three and four transform based watermarking algorithms are applied to CT, MRI, X-ray and ultrasound modalities of various organs such as knee, lung, brain and backbone independently and also to a single organ knee and their performance was evaluated by applying various attacks. In these cases patient information is used as the watermark.

1. Introduction

People living in rural and remote areas are struggling to access timely, good-quality specialty medical care because specialist physicians are more likely to be located in urban areas. Telemedicine has the potential to bridge this distance and facilitate healthcare in these remote areas. “Tele” is a Greek word meaning “distance” and “mederi” is a Latin word meaning “to heal”. i.e. “healing by wire” was initially considered as “futuristic” and “experimental” but today has a variety of applications in patient care, education, research, administration and public health. The following issues of medical data motivated us to work in this present research work [1].

- i. Preserving the security and authenticity of medical images, while distributing the medical images between hospitals due to an ever-increasing demand for telemedicine.
- ii. Providing imperceptibility and security for patient information due to the usage of EHR is a big challenge.
- iii. While transmission protecting the medical data against various attacks such as filtering, compression, cropping and noise is still a problem.

The objectives of the present work are to

- i. To Propose more robust hybrid watermarking method by combining three and four transform techniques such as Discrete Wavelet Transform (DWT), Contourlet Transform (CT), Discrete Cosine Transforms (DCT) and Singular Value Decomposition (SVD).
- ii. To evaluate the hybrid watermarking algorithm against attacks such as filtering, compression, cropping and noise.
- iii. To determine the authenticity of medical imaging data of various modalities of various patients by using the proposed hybrid algorithm.

2. Hybrid Watermarking Methods

2.1. Introduction

Watermarking methods are classified as time or frequency (transform) domain methods. Transform domain watermarking techniques apply some invertible transform to the host image before embedding the watermark. Then the transform domain coefficients are modified to embed the watermark and finally the inverse transform is applied to obtain the watermarked image. The watermark, embedded in the transform domain method is irregularly distributed over the local area hence these methods make the attacker difficult to extract or modify the watermark [2]. The transforms commonly used for hybrid watermarking methods are Contourlet Transform (CT), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD) etc. Sometimes two or more transforms like DWT - DCT, DCT - SVD, DWT - SVD, DWT- DCT-SVD, CT – DCT, and CT – SVD etc can be combined to enhance imperceptibility, reliability and robustness of the hybrid algorithm [3].

2.2. Proposed Methods

In the current research work, two hybrid watermarking techniques are proposed by combining three (CT, DCT, SVD) and four (DWT, CT, DCT, SVD) transforms and

they were benchmarked against various attacks. The proposed algorithms are used for the authentication of multi-modal medical imaging modalities such as X-Ray, CT, MRI, and Ultra-sound [4]. A complete digital watermark system is composed of three steps, i.e. 1. watermark creation and embedding 2. watermark extraction, and 3. performance evaluation. These three steps are explained below.

2.2.1 Watermark Embedding Process

An input original image and watermark image are considered and coefficients are generated by applying DWT, CT, DCT and SVD respectively. Watermark coefficients are then embedded in the original image by applying embedding algorithm [5]. In this case 512X512 Lena image, CT, MRI, X-ray and Ultrasound images of brain, backbone, lungs etc are used as input images 256X256 watermark is embedded in that. The embedding process is shown in Figure.2.1.

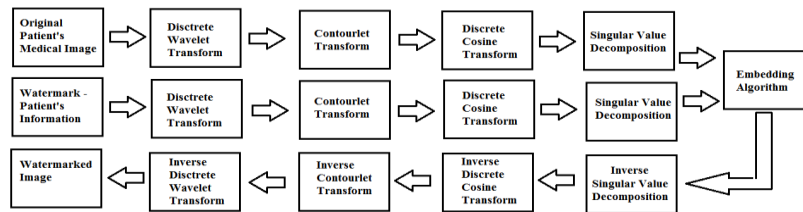


Figure 2.1: Block Diagram of Watermark Embedding Process
(DWT, CT, DCT, and SVD)

2.2.2. Watermark Embedding Algorithm

- Consider patient's medical image as an original image i.e. Lina, X-Ray, CT, MRI, and Ultrasound imaging modalities.
- Prepare the watermark by using patient's information such as name, age, gender, and problem description.
- Apply 2-level DWT to original image and watermark.
- The image is decomposed into approximate and detailed images.
- The approximate image is an LL sub-band, which consists of lower frequency coefficients.
- The detail images are LH, HL, and HH sub-bands, they consist of high frequency coefficients.
- Apply CT for an obtained output image from DWT.
- CT consists of Laplacian pyramid and Directional Filter Bank (DFB), the combination of these two are called Pyramidal Directional Filter Bank (PDFB).
- Apply DCT to each block of an image by making image into 8x8 blocks. These blocks are denoted with subscript i . Where $i = 1, 2, \dots, M$, where $M \leq N_w \cdot N_w$ is the watermark bits, it is product of L_w and H_w .
- Apply SVD to all non-overlapping 8x8 blocks. SVD is an orthogonal transform used for matrix diagonalization. It is decomposed into product of three matrices. This decomposition is known as SVD.
- To embed watermark into the produced blocks, the middle frequency coefficients of each block are selected. This selection is a tradeoff between robustness and imperceptibility of watermark. $\bar{S} = S_{oi} + \alpha W$ Where α is the watermark strength

- l. The watermark is inserting in the original image by using embedding algorithm.
- m. Perform Inverse SVD, Inverse DCT, Inverse CT and Inverse DWT for reconstruction of image and to get the watermarked image.

2.2.3. Watermark Extraction Process

To extract the watermark from the 512x512 watermarked image and 512x512 cover image are used. The watermark (Patient's information) is extracted from the watermarked image by using extraction algorithm [6] as shown in Figure.2.2.

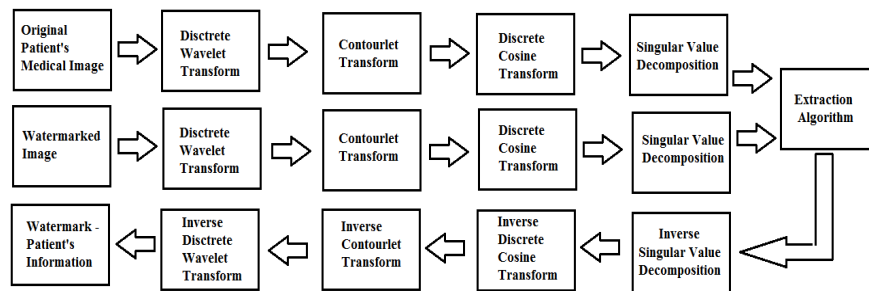


Figure 2.2: Block Diagram of Watermark Extraction Process

2.2.4. Watermark Extraction Algorithm

Consider the watermarked image and patient's medical data such as X-Ray, CT, MRI, and Ultrasound imaging modalities or Lena as cover image. These two after application of transforms can be fed to the extraction algorithm. After watermark extraction the similarity can be measured between reconstructed and original watermarks [7].

- a. Apply 2-level DWT to original image and watermarked image.
- b. The image is decomposed into approximate and detail images.
- c. The approximate image is an LL sub-band, which consists of lower frequency coefficients.
- d. The detail images are LH, HL, and HH sub-bands, they consist of high frequency coefficients.
- e. Apply CT to an obtained output image from DWT.
- f. CT consists of Laplacian Pyramid (LP) and Directional Filter Bank (DFB), the combination of these two are called Pyramidal directional filter bank (PDFB).
- g. Apply DCT to each block of an image; an image is divided into 8x8 blocks. These blocks are denoted as subscript i.

Where $i = 1, 2, \dots, M$, where $M \leq N_w$.

N_w is the watermark bits (product of L_w and H_w)

- h. Apply SVD to all non-overlapping 8x8 blocks. SVD is an orthogonal transformation used for matrix diagonalization. It is decomposed into product of three matrices. This decomposition is known as SVD.
- i. The watermark is extracting from the watermarked image with original image by using extraction algorithm.
- j. Apply SVD on each block and Extract the singular values of the watermark.

$$W_{ext} = \frac{\text{Output} - \text{Soi}}{\alpha} \quad \text{where } \alpha \text{ is strength parameter}$$

- k. Perform Inverse SVD, Inverse DCT, Inverse CT and Inverse DWT for the extraction of the watermark.

2.3. Performance Evaluation

Performance of the proposed methods can be evaluated by using different parameters like imperceptibility, robustness and reliability. These parameters are quantitatively expressed in terms of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Normalized Cross Correlation (NCC), and Similarity [8]. Mathematical definitions used for four parameters given in Table 2.1.

Table 2.1: Mathematical Expressions for Performance Metrics

S.No.	Name of the Parameter	Mathematical Expression
1	PSNR	$20 \log_{10} \left(\frac{255}{\sqrt{MSE}} \right)$
2	MSE	$\frac{1}{MN} \sum_{x=1}^M \sum_{y=1}^N [I(x,y) - I'(x,y)]^2$
3	NCC	$NCC = \frac{\sum_{x=1}^M \sum_{y=1}^N [I(x,y) - \bar{I}(x,y)][I'(x,y) - \bar{I}'(x,y)]}{\sqrt{\sum_{x=1}^M \sum_{y=1}^N [I(x,y) - \bar{I}(x,y)]^2} \sqrt{\sum_{x=1}^M \sum_{y=1}^N [I'(x,y) - \bar{I}'(x,y)]^2}}$
4	Similarity	$Similarity = \frac{\sum_{x=1}^M \sum_{y=1}^N W(x,y) * W'(x,y)}{\sum_{x=1}^M \sum_{y=1}^N [W'(x,y)]^2}$

2.4. Mathematical Kernals

2.4.1 Contourlet Transform (CT): CT is a geometrical transform which can efficiently capture multi-scale image edge information in all directions. It consists of two major parts, the Laplacian Pyramid (LP) and Directional Filter Bank (DFB) as shown in Figure 2.3. It has inherent characteristics of directionality and anisotropy, which makes it better than the popular DWT [9].

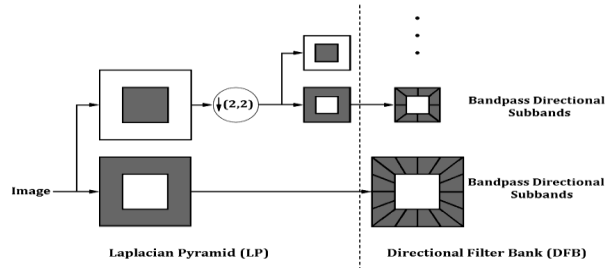


Figure 2.3: Contourlet Transform

2.4.2 Discrete Wavelet Transform (DWT): The wavelet transform involves projecting a signal onto a complete set of translated and dilated versions of a mother wavelet $\Psi(t)$.

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right); a, b \in \mathfrak{R} \text{ and } a > 0 \text{ \{ '}\mathfrak{R}' \text{ refers to set of real numbers} \}$$

A mother wavelet and its scaled versions are depicted below indicating the effect of scaling in Figure 2.4.

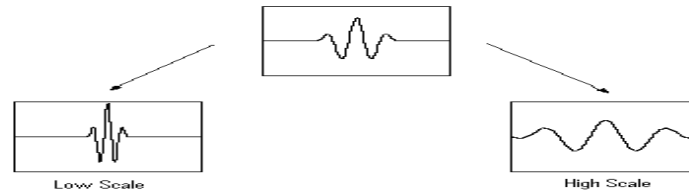


Figure 2.4: Mother Wavelet and its Scaled Versions

When one-level 2-D DWT is applied to an image, four transform coefficient sets are created. As depicted in Figure 2.5 the four sets are LL, HL, LH, and HH, where the first letter corresponds to applying either a low pass or high pass filter to the rows, and the second letter refers to the filter applied to the columns. The time localization will have a resolution that depends on which level they appear [10].

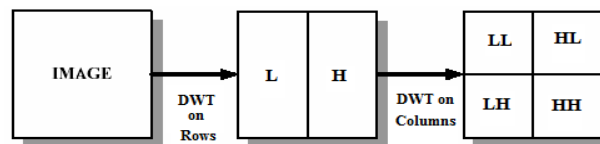


Figure 2.5: Level One 2D- DWT Applied on an Image

DWT generates a data structure known as scale space representation. In this image representation, the high frequency signals are precisely located in the pixel domain, while low frequency signals are precisely located in the frequency domain. The spatial resolution increases with increase in frequency. Therefore sharp edges which are localized spatially and have a significantly high frequency content, can be seen in the detail sub bands and form the contours of the image's objects. While the frequency resolution is independent of the frequency in the DCT domain [11].

2.4.3 Discrete Cosine Transform (DCT): DCT the data is represented as frequency space breaks the image into low, middle and high frequencies, thus making the embedding into mid frequency band easy [12].

2.4.4 Singular Value Decomposition (SVD): It is important to note that each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image. In SVD-based watermarking, a common approach is to apply SVD to the whole cover image, and modify all the singular values to embed the watermark data [13]. It is a kind of orthogonal transforms used for matrix diagonalization. An image can be viewed as a non-negative real matrix. Let A be an image, and its size be $M \times N$.

The SVD of A can be described as $A = U D V^T$, where U and V are orthogonal matrices. The diagonal entries of D are called the singular values of A , the columns of U are called the left singular vectors of A , and the columns of V are called the right singular vectors of A . This decomposition is known as the Singular Value Decomposition (SVD) of A [14].

Mathematical expressions used for transforms shown in Table 2.2:

Table 2.2: Mathematical Expressions for Considered Transforms in 2D

S.No.	Name of the Transform	Mathematical Expression
1	DWT	For approximate coefficients: $w_{\phi}(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \phi_{j_0, m, n}(m, n)$ For detailed coefficients: $w_{\psi}^i(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \psi_{j_0, m, n}^i(m, n)$
2	Inverse DWT	$f(x, y) = \frac{1}{\sqrt{MN}} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} w_{\phi}(j_0, m, n) \phi_{j_0, m, n}(x, y) + \frac{1}{\sqrt{MN}} \sum_{i=-H/2}^{\infty} \sum_{j=j_0}^{\infty} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} w_{\psi}^i(j_0, m, n) \psi_{j_0, m, n}^i(x, y)$
3	DCT	$C(u, v) = \alpha(u)\alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x, y) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right]$
4	Inverse DCT	$f(x, y) = \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} \alpha(u)\alpha(v) C(u, v) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right]$
5	SVD	$A = UDV^T, \quad A = [u_1 \ u_2 \ \dots \ u_N] \begin{bmatrix} \lambda_1 & & & \\ & \ddots & & \\ & & \lambda_R & \\ & & & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_N \end{bmatrix} \quad A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + \dots + \lambda_R U_R V_R^T$
6	CT	$X_{H0}(i, j) = X(i, j) - X_{10}^*(i, j)$

2.5. Medical Imaging Modalities for Watermarking

There are four medical imaging modalities such as X-Ray, Ultrasound, Computed (Axial) Tomography (CT) and Magnetic Resonance Imaging (MRI) considered in this work for the authentication of patient's medical data. Patient details such as name, age, gender and problem are used in the construction of watermark [15].

2.5.1. Ultrasound

Diagnostic ultrasound, also known as medical sonography or ultrasonography, uses high frequency sound waves to create images of the inside of the body. The ultrasound machine sends sound waves into the body and is able to convert the returning sound echoes into a picture [16].

Ex: Pregnancy.

2.5.2. X-Ray

It uses a small amount of radiation that passes through the body, quickly capture a single image of your anatomy to assess injury (fractures or dislocations) or disease (bone degeneration, infections or tumors). Dense objects, such as bone, block the radiation and appear white on the X-ray picture. Radiologists review the pictures and create a report with their findings to aid in diagnosis [17].

2.5.3. Computed (Axial) Tomography (CT or CAT Scan)

It is a rapid 5-20 minute painless exam that combines the power of X-rays with computers to produce 360 degree, cross-sectional views of your body. CT is able to image bone, soft tissue and blood vessels all at the same time. It provides the radiologist with details of bony structures or injuries, diagnosing lung and chest problems, and detecting cancers. CT is good for imaging bone, soft tissue and blood vessels [18].

2.5.4. Magnetic Resonance Imaging (MRI)

It combines a powerful magnetic field with an advanced computer system and radio waves to produce accurate, detailed pictures of organs, soft tissues, bone and other

internal body structures. Differences between normal and abnormal tissue is often clearer on an MRI than CT. There is no radiation exposure with MRI machines. MRI is good imaging organs, soft tissue an internal structures (spine scan image). MRI is a medical imaging technology that uses radio waves and a magnetic field to create detailed images of organs and tissues. MRI has proven to be highly effective in diagnosing a number of conditions by showing the difference between normal and diseased soft tissues of the body [19]. MRI is often used to evaluate: Blood vessels, Abnormal tissue, Breasts, Bones and joints, Organs in the pelvis, chest and abdomen (heart, liver, kidney, spleen), Spinal injuries, Tendon and ligament tears. The mathematical principles on which medical imaging modalities of Patient's leg knee image will work is shown in table 2.3.

Table 2.3: Original Medical Imaging Modalities with Mathematical Expressions

S.No	Description	Modality			
		X-Ray	CT	Ultra - Sound	MRI
1	Medical Images				
2	Mathematical Formulae	$\phi V = h \phi_{max}, \lambda_{pvt} = \frac{C}{\phi_{max}} = \frac{h C}{\phi V}$ $I(x, y) = I_0 e^{-\int_{path} \mu(x, y) ds}$ $\nabla^2 \phi = \frac{1}{C^2} \frac{\partial^2 \phi}{\partial t^2}$ $\frac{dM}{dt} = \gamma M \times H - \frac{M_{xy}}{T_2} - \frac{M_z - M_0}{T_1}$			

2.6. Attacks

The proposed algorithms are benchmarked/ validated by applying attacks such as filtering, compression, and geometrical attacks such as cropping and noise [20]. The mathematical models for all the above mentioned attacks are represented in Table 2.4.

Table 2.4: Mathematical Representations for All Attacks Used

S.No	Attacks	Mathematical Representation
1	Pyramid	Gaussian Pyramid: $g_k = REDUCE(g_{k-1})$ For levels $0 \leq l \leq N$ and nodes i, j $0 \leq i \leq C_l$ $0 \leq j \leq R_l$ $g_l(i, j) = \sum_{m=-2}^2 \sum_{n=-2}^2 w(m, n) g_{l-1}(2i + m, 2j + n)$ Laplacian Pyramid: $g_{l,n} = EXPAND(g_{l,N-1})$ $L_l = g_l - EXPAND(g_{l-1}(i, j))$ $g_l = L_l + EXPAND(g_{l-1}(i, j))$ For levels $0 \leq l \leq N$ and $0 \leq n \leq nodes$ i, j $0 \leq i \leq C_{l-n}$ $0 \leq j \leq R_{l-n}$ $g_{l,n}(i, j) = 4 \sum_{m=-2}^2 \sum_{n=-2}^2 w(m, n) \cdot g_{l,n-1}(\frac{i-m}{2}, \frac{j-n}{2})$
2	DCT	DCT: $C(u, v) = \alpha(u) \alpha(v) \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} f(x, y) \cos\left[\frac{\pi(2u+1)n}{2N}\right] \cos\left[\frac{\pi(2v+1)m}{2N}\right]$ IDCT: $f(x, y) = \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} \alpha(u) \alpha(v) C(u, v) \cos\left[\frac{\pi(2u+1)n}{2N}\right] \cos\left[\frac{\pi(2v+1)m}{2N}\right]$
3	JPEG2000	For approximate coefficients: $w_0(l_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} f(x, y) \phi_{l_0, m, n}(m, n)$ For detailed coefficients: $w_0^i(l_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} f(x, y) \phi_{l_0, m, n}^i(m, n)$ IDWT: $f(x, y) = \frac{1}{\sqrt{MN}} \sum_{i=0}^{M-1} \sum_{m=0}^{N-1} w_0^i(l_0, m, n) \phi_{l_0, m, n}(x, y) + \frac{1}{\sqrt{MN}} \sum_{i=0}^{M-1} \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} w_0^i(l_0, m, n) \phi_{l_0, m, n}^i(m, n)$
4	B-T	Mean: $\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$ Standard Deviation: $\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2}$ $\bar{x}$ = Threshold value of bit - plane Block of pixel: $B = \begin{cases} 1, & x_i \geq \bar{x} \\ 0, & x_i < \bar{x} \end{cases}$ High intensity: $H = \bar{x} + \sigma \sqrt{\frac{p}{q}}$ Low intensity: $L = \bar{x} + \sigma \sqrt{\frac{q}{p}}$
5	Filtering	Low-pass: $H(u, v) = e^{-(u^2 + v^2)/2\sigma^2}$ High-pass: $H(u, v) = 1 - e^{-(u^2 + v^2)/2\sigma^2}$ Merdim: $V(m, n) = \sum_{k,l} a(k, l) y(m-k, n-l)$
6	Geometrical	Gaussian Noise: $f(Z) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\left(\frac{Z-\mu}{\sigma}\right)^2}$ Cropping: $y(m_1, m_2) = x(n_1, n_2) + z(m_1, m_2)$

3. Results and Conclusions

Results

Proposed three and four transform methods are simulated in MATLAB and the results are compared with the existing method [28] are shown in Table.3.1. The graphical representation of the same [29] is also shown in Figure.3.1. The watermarked image

and extracted watermark of the respective methods is shown in Figure.3.2. From the results it is observed that four transform method is more imperceptible and robust [21] [30].

Table 3.1: Performance Comparison of Proposed Methods

Transform	Similarity	NCC	MSE	PSNR[dB]
DWT-DCT-SVD(Existing)	0.99513	0.9992	6.8247	39.79
CT-DCT-SVD(Proposed1)	0.99804	0.9999	0.1115	57.66
DWT-CT-DCT-SVD (Proposed2)	0.99918	1.0000	0.0170	65.82

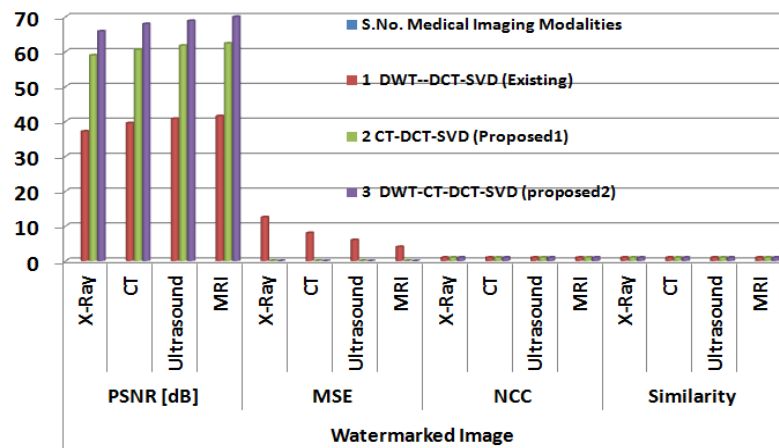


Figure 3.1: Performance Comparison of Proposed Methods

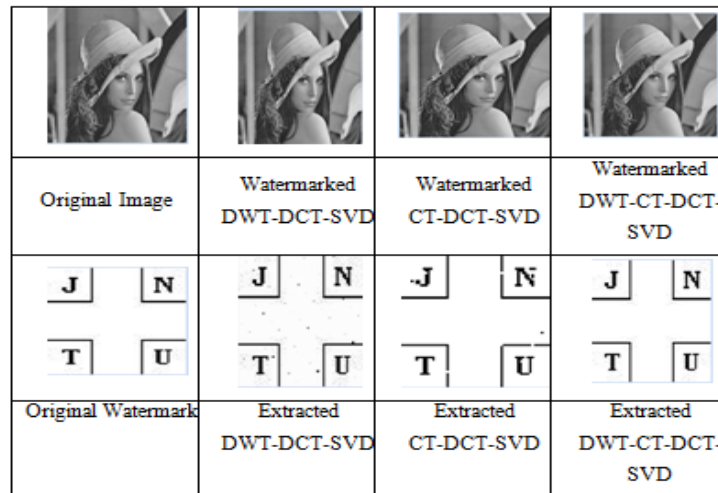


Figure 3.2: Watermarked Image and Extracted Watermark

ATTACKS: The proposed algorithm is validated by applying filtering, geometrical transforms, compression and noise attacks on the same images. The reconstructed watermarked images and watermarks are compared by using performances metrics[22]. The results are shown in Table.3.2.and Figure 3.3. respectively.

Table 3.2: Performance Evaluation of against Attacks

Types of Single/Hybrid Transform(s)	DWT-DCT-SVD (Existing)				CT-DCT-SVD (Proposed1)				DWT-CT-DCT-SVD (Proposed2)			
Image after/before attacks	Similarity	NCC	MSE	PSNR[dB]	Similarity	NCC	MSE	PSNR[dB]	Similarity	NCC	MSE	PSNR[dB]
Watermarked Image	0.99513	0.99919	6.8247	39.79	0.99804	0.99998	0.11146	57.6596	0.99918	1	0.017012	65.8233
Low-Pass Filtering	0.81384	0.7496	27.634	33.7164	0.81549	0.97564	25.4035	34.0819	0.88495	0.9756	25.405	34.0816
Median Filtering	0.98557	0.99864	4.3349	41.761	0.98815	0.99948	1.2135	47.2905	0.99399	0.99984	0.36528	52.5046
High-Pass Filtering	0.030443	0.2178	254.5896	624.0724	0.029986	0.21908	254.5985	24.0722	0.041356	0.21949	254.5879	24.0724
Pyramid Compression	0.83958	0.97359	26.8899	33.8349	0.84008	0.97217	26.4633	33.9044	0.93654	0.99011	14.0726	36.6471
DCT Compression	0.78182	0.96645	37.2406	32.4206	0.78293	0.96491	36.6369	32.4916	0.87016	0.96489	36.6433	32.4909
JPEG2000 Compression	0.86523	0.98824	20.6965	34.9718	0.86466	0.98757	20.44448	35.025	0.91584	0.98759	20.4092	35.0325
Cropping	0.539	0.35439	100.1907	28.1225	0.55819	0.42361	96.874	28.2687	0.7021	0.4316	93.3479	28.4298
Gaussian Noise	0.69345	0.9618	95.155	41.0085	0.71412	0.96046	2.02	45.0773	0.71705	0.9606	1.6647	45.9174

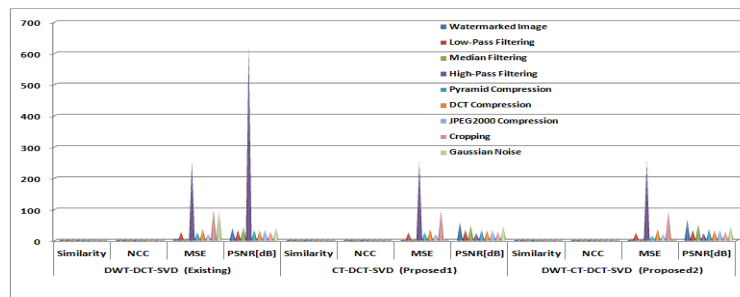


Figure 3.3: Performance Evaluation after Application of Attacks

SECURITY EVALUATION OF MEDICAL IMAGING MODALITIES: After validation algorithm is used for the security preservation of medical modalities of patient's information in telemedicine of various organs [23] as shown in Figure 3.4.

Method	Medical Imaging Modalities			
	X-Ray	CT	MRI	Ultrasound
Original Image				
Original Watermark				
Watermarked Images (DWT-DCT-SVD) (Existing)				
Extracted Watermark (DWT-DCT-SVD) (Existing)				
Watermarked Images (CT-DCT-SVD) (Proposed1)				
Extracted Watermark (CT-DCT-SVD) (Proposed1)				
Watermarked Images (DWT-CT-DCT-SVD) (Proposed2)				
Extracted Watermark (DWT-CT-DCT-SVD) (Proposed2)				

Figure 3.4: Watermarked Modalities and Extracted Watermarks

Multi Modal Medical Image Watermarking

Watermark formation form Patient's Information: In this case medical information of the patient is formed as a watermark [24] as shown in Figure.3.5. and embedded in concern modalities of the knee organ [25] as shown in Figure.3.6. The performances metrics [26] are indicated in Table.3.3. The method is also validated by applying attacks Filtering, compression, cropping and noise [27] and results are shown in Figure.3.7- 3.10. respectively.

AV 38
M KNEE

Figure 3.5: Watermark Formation from Patient Data Modalities

Table 3.3: Performance Metrics of Knee for X-Ray, CT, Ultrasound and MRI

S.No.	Medical Imaging Modalities	Watermarked Image											
		PSNR [dB]				MSE				NCC			
		X-Ray	CT	Ultrasound	MRI	X-Ray	CT	Ultrasound	MRI	X-Ray	CT	Ultrasound	MRI
1	DWT-DCT-SVD (Existing)	37.12	39.52	40.75	41.54	12.531	8.0152	6.0143	4.0132	0.9861	0.9873	0.9884	0.9921
2	CT-DCT-SVD (Proposed1)	58.93	60.54	61.72	62.35	0.081	0.0752	0.0643	0.0532	1	1	1	1
3	DWT-CT-DCT-SVD (proposed2)	65.82	67.92	68.82	69.99	0.02	0.0152	0.0143	0.0132	1	1	1	1

S.No.	Method	Images	Medical imaging Modalities			
			X-Ray	CT	Ultra-Sound	MRI
1	-	Original image				
2	-	Original Watermark	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE
3	DWT-DCT-SVD(Existing)	Watermarked images				
		Extracted Watermark	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE
4	CT-DCT-SVD(Proposed1)	Watermarked images				
		Extracted Watermark	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE
5	DWT-CT-DCT-SVD(Proposed2)	Watermarked images				
		Extracted Watermark	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE	AV 38 M KNEE

Figure 3.6: Watermarked image and Extracted Watermarks of X-Ray, CT, Ultrasound and MRI of Knee Organ

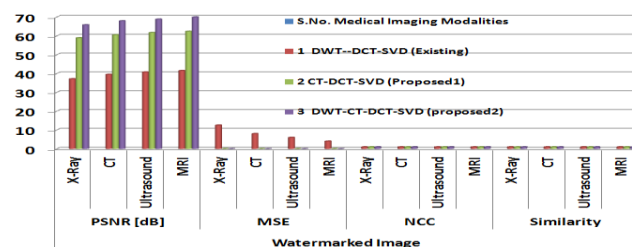


Figure 3.7: Performance Evaluation of Medical Modalities for Knee Organ for Watermarked Image

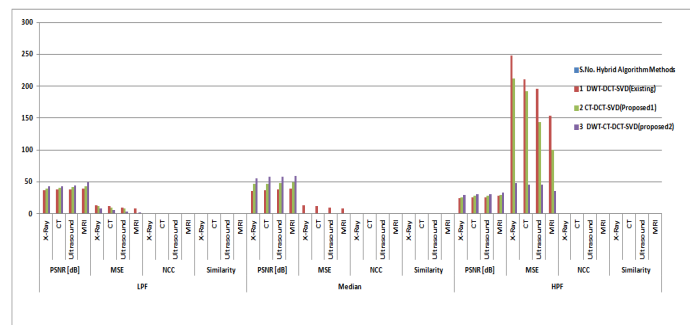


Figure 3.8: Performance Evaluation of Medical Modalities for Knee Organ for Filtering

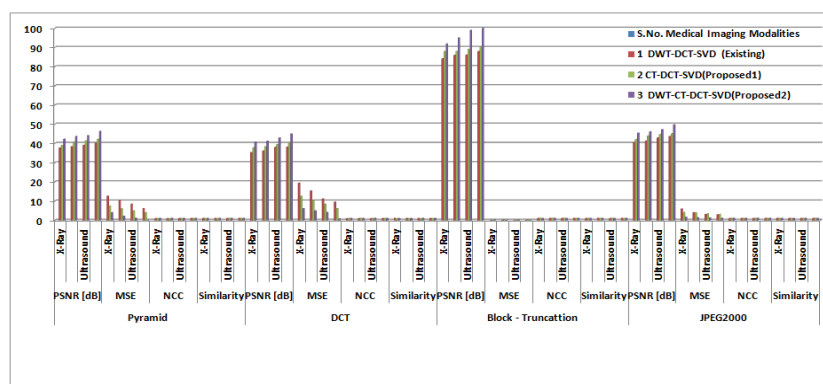


Figure 3.9: Performance Evaluation of Medical Modalities for Knee Organ for Compression

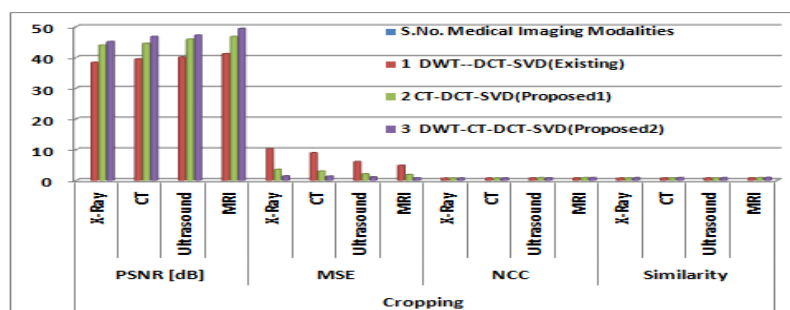


Figure 3.10: Performance Evaluation of Medical Modalities for Knee Organ for Cropping

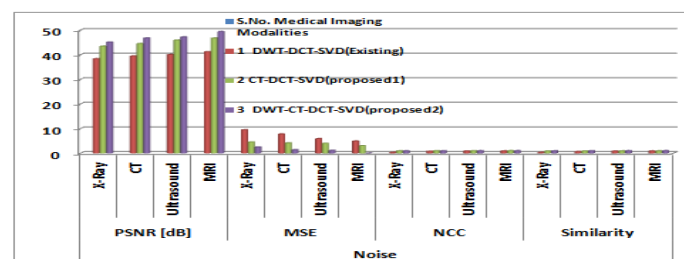


Figure 3.11: Performance Evaluation of Medical Modalities for Knee Organ for Noise

Conclusions

Proposed Methods

Three transform method: Proposed method (CT, DCT, SVD) is more imperceptible, robust and reliable compared to existing method (DWT,DCT, SVD) as per table.3.1. Similarity increases means that extracted watermark is less distorted i.e. more robust, in the proposed method rather than the existing method. Correlation (NCC) and PSNR also increases means that reconstructed watermarked image is more imperceptible i.e. watermark presence could not change the appearance of the original image. Reconstructed watermark image is same as the original image. Error(MSE) present is also less compared to the existing Method. This is due to the replacement of existing DWT with CT. DWT can consider the scale issues but not curved information. Whereas CT covers curved information.DCT covers compaction and SVD takes care of the eigen values. Hence this combination of hybrid algorithm producing better results than the existing one.

Four transform method: (DWT, CT, DCT, SVD) When DWT is also added to the CT, DCT and SVD it also includes the multi-resolution and localization in space and time properties of the proposed1. Hence is much robust and reliable than proposed1 as shown in Table.3.1.

Validation: Proposed1 and 2 are validated by applying filtering (Low, Median and high pass), Compression (pyramid, block truncation and JPEG2000), cropping and Gaussian Noise. The results are shown in Table.3.2. and Figure.3.3. Out of filtering attacks median filtering has less impact on watermarked image. High pass filtering is distorting more. This distortion is less in the proposed methods compared to existing. Though block truncation is appropriate but it is not able to distinguishable in various methods hence JPEG2000 results are better. Noise and cropping performance also improved in the proposed methods.

Security for Medical Data: These methods are working good for modalities such as X-ray, CT, Ultrasound and MRI as per Figure.3.4. When they are attacked while transmission also security is restoring as per Figures.3.7- 3.10. In the proposed case patient information is added as watermark and hence EHR need not transfer to the other end.

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