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ROI Based Embedded Watermarking of Medical Images for Secured Communication in Telemedicine

Baisa L. Gunjal, Suresh N. Mali

***Abstract*—**Medical images require special safety and confidentiality because critical judgment is done on the information provided by medical images. Transmission of medical image via internet or mobile phones demands strong security and copyright protection in telemedicine applications. Here, highly secured and robust watermarking technique is proposed for transmission of image data via internet and mobile phones. The Region of Interest (ROI) and Non Region of Interest (RONI) of medical image are separated. Only RONI is used for watermark embedding. This technique results in exact recovery of watermark with standard medical database images of size 512x512, giving 'correlation factor' equals to 1. The correlation factor for different attacks like noise addition, filtering, rotation and compression ranges from 0.90 to 0.95. The PSNR with weighting factor 0.02 is up to 48.53 dBs. The presented scheme is non blind and embeds hospital logo of 64x64 size.

***Keywords*—**Compression, DWT, ROI, Scrambling, Vertices

I. Introduction

TELEMEDICINE combines Medical Information System with Information Technology that includes use of computers to receive, store and distribute medical information over long distances. Telemedicine can be divided into number of medical related technologies using computers for healthcare like teleradiology, telepathy, telecare, telesurgery, teleneurology etc[3][4]. In number of medical applications, medical images require special safety and confidentiality, because critical judgment is done on the information provided by medical images. Critically ill or injured patients can be treated locally by effective and secured communication between remote hospitals and distant specialist [2]. Exchange of medical images between hospitals located in different geographical locations is a common practice now a day as shown in fig 1. Hence, healthcare industry demands secure, robust and more information hiding techniques promising strict secured authentication and communication through internet or mobile phones. Digital image watermarking provides copyright protection to digital image by hiding appropriate information in original image to declare rightful ownership. There are four essential factors those are commonly used to determine quality of watermarking scheme. They are robustness, imperceptibility, capacity, and blindness [21].

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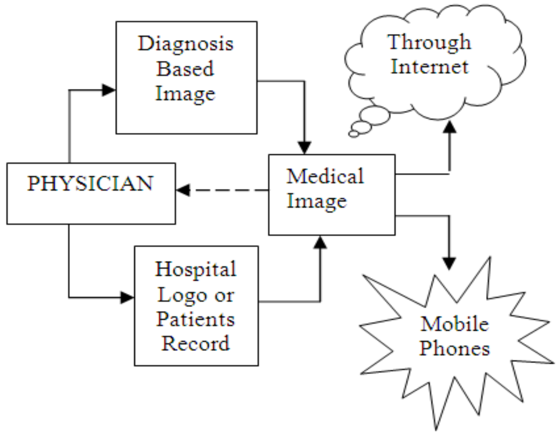


Fig. 1 Transmission of medical images from physician of remote hospital to specialist through internet and mobile phone

II. Survey

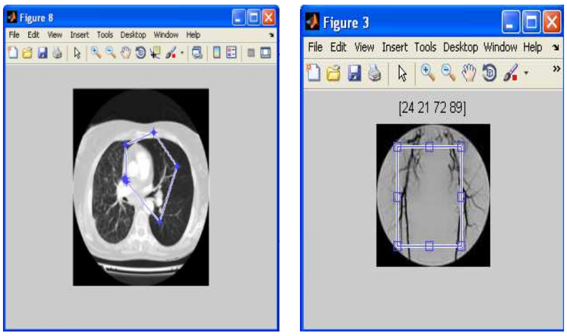
LSB based watermarking in spatial domain is the straightforward method, But LSB based watermarking as well as LSB based watermarking with pseudo random generator are not secured methods [10]. In Continuous Wavelet Transform, Calculating wavelet coefficients at every possible scale is huge amount of work and it generates a lot of data. There is highly redundant information as per as the reconstruction of the signal is concerned. Due to the attractive features of Discrete Wavelet Transform, researches have been focused on DWT [13]. Wang Hongjun, Li Na have proposed a DWT based method [14] in which watermark was embedded in middle frequency coefficient using α as flexing factor with $\alpha = \beta|m|$,where m is mean value of all coefficients watermarking embedded. But this method doesn't provide enough security. The method proposed in [14] using DWT was extended in [1] to enhance security of algorithm by using Arnold's Transform pretreatment for watermark. But this method can be extended to improve PSNR and security levels. As given in [15], two phase watermark embedding process was carried out using DWT. Phase 1: Visible watermark logo embedding, Phase 2: Feature extracted watermark logo embedding. The algorithm was based on texture based watermarking. A Integer Wavelet Transform with bit plane complexity segmentation is used with more data hiding capacity [17]. But this method needs separate processing for R, G and B components of color image. As given in [16] using DWT, host image is decomposed into 3 levels recursively. In level one we get 4 sub bands. In level 2, each sub band of level 1 is divided to 4 sub bands to give total 16 sub bands. Finally, each sub band of level 2 is again divided into 4 sub bands each to give total 64 sub bands. Then 'generic algorithm' was applied to find the best sub band for watermark embedding to provide perceptual transparency and robustness. But the process is too lengthy and time consuming. The common problem with DCT watermarking is block based scaling of watermark image changes scaling factors block by block and results in visual discontinuity.[6][18]. As given in [19], J. Cox et. al had presented 'spread spectrum based watermarking schemes', Chris Shoemaker has developed CDMA based spread spectrum watermarking with one scale DWT and got PSNR between 35-40 db for various attacks. As given in [20], Harsh Varma et. al tested CDMA based watermarking scheme with spatial domain and frequency domain with DCT as well as DWT. But these algorithms have low information hiding capacity.

III. Foundations Of Our Method

This section explains details of Region of Interest (ROI) and RONI (Region of Non interest), Discrete Wavelet Transform (DWT) and Arnold Transform used for watermark scrambling.

A. Importance And Processing Of (Roi)

Conventional watermarking systems embed the hidden information in the entire image. This is not acceptable for the sensitive imagery like medical images. A medical image contains ROI: Region of Interest and RONI: Non Region of Interest. ROI is sensitive region of medical image using which doctors do exact diagnosis and decide treatment according [3].

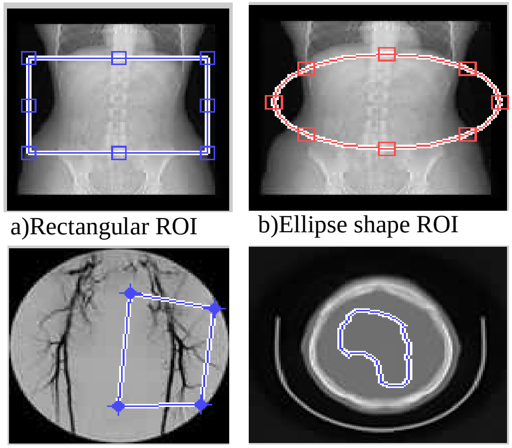


a)Selecting ROI directly b)Selecting ROI with tool

Fig. 2 Selecting ROI for image under diagnosis

Use of classical watermarking techniques may create the distortion in ROI and consequently the diagnosis value of image may be lost. Hence, only RONI should be used for watermark embedding. The ROI of image can be selected interactively from medical image. Excluding such selected region, the watermark is embedded. Fig 2:a) and fig 2:b) shows separation of ROI in Matlab from given image under diagnosis. The ROI can be selected interactively in fig 2: a) or it can be separated effectively using ROI tool as shown in fig 2 b). The physician can use different options to select ROI interactively. Fig 3 shows some of the options including: rectangular, ellipse shaped, polygon with n number of vertices or selection with free hand. Thus, ROI and RONI of image are needed to be separated before watermark embedding.

The watermark is embedded with pixels of RONI and watermarked image is constructed.

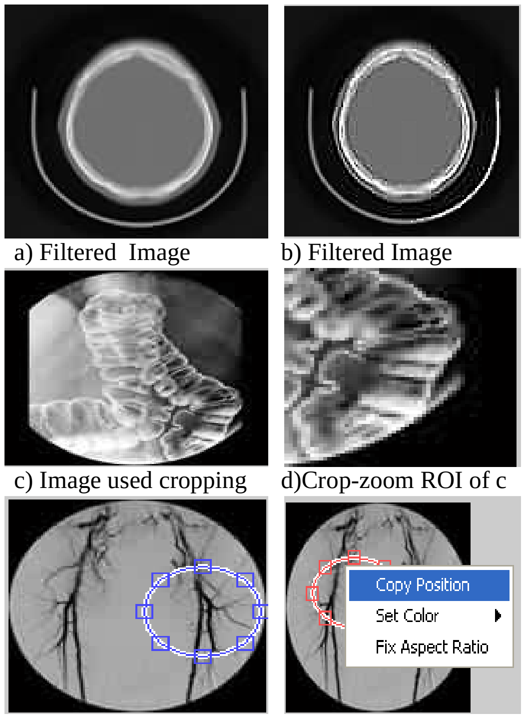


a)Rectangular ROI b)Ellipse shape ROI

c)ROI with polygon d)Free hand ROI

Fig. 3 Options for selecting ROI for medical image

Many times for proper diagnosis of image, ROI is also need to be processed. e.g. as shown in fig 4, filtering of ROI to remove unwanted noise is required.



a) Filtered Image b) Filtered Image

c) Image used cropping d)Crop-zoom ROI of c

e)Creating Binary Mask f) Copy Mask position

Fig. 4 Processing of ROI of image under diagnosis

B. Discrete Wavelet Transform

DWT has become researchers focus for watermarking as DWT is very similar to theoretical model of Human Visual System (HVS). ISO has developed and generalized still image compression standard JPEG2000 which substitutes DWT for DCT. Discrete wavelet can be represented as

$$\psi_{j,k}(t) = a_0^{-j/2}\psi\,(a_0^{-j}t - k\,b_0) \qquad (1)$$

For dyadic wavelets a_0 =2 and b_0 =1, Hence we have,

$$\psi_{j,k}(t) = 2^{-j/2}\psi\,(2^{-j}t - k\,) \qquad \text{j, k} \in Z \qquad (2)$$

Image itself is considered as two dimensional signals. When image is passed through series of low pass and high pass filters, DWT decomposes the image into sub bands of different resolutions [11][12]. Decompositions can be done at different DWT levels e.g. fig 5 shows 3 level decomposition.

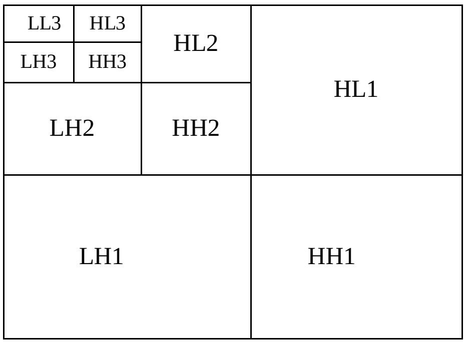


Fig. 5 Decomposition of image up to 3 levels

The sample decomposition and reconstruction in Wavelet toolbox is shown in fig 6 a. Fig 6 b. show histogram of original image and reconstructed image are same indicating exact construction of image.

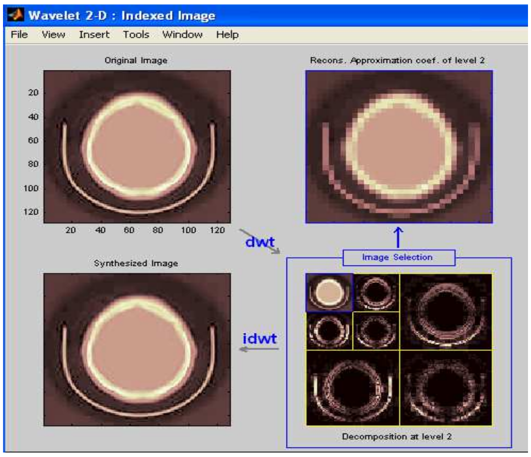


Fig. 6 a) Decomposition up to 3 levels and reconstruction (Synthesized) of image

Here, DWT decomposes image into four non overlapping multi resolution sub bands: LL3x (Approximate sub band), HLx (Horizontal sub band), LHx (Vertical sub band) and HHx (Diagonal Sub band). Here, LLx is low frequency component whereas HLx, LHx and HHx are high frequency (detail) components [7][8][9]. To obtain next coarser scale of wavelet coefficients after level 1, the sub band LL1 is further processed until final N scale reached. When N is reached, we have 3N+1 sub bands with LLx (Approximate Components.) and HLx, LHx, HHx (Detail components) where x ranges from 1 to N. Three level image decomposition is shown in Fig :1. Embedding watermark in low frequency coefficients can increase robustness significantly but maximum energy of most of the natural images is concentrated in approximate (LLx) sub band. Hence modification in this low frequency sub band will cause severe and unacceptable image degradation. Hence watermark is not be embedded in LLx sub band. The good areas for watermark embedding are high frequency sub bands (HLx, LHx and HHx), because human naked eyes are not sensitive to these sub bands. They yield effective watermarking without being perceived by human eyes. But HHx sub band includes edges and textures of the image. Hence HHx is also excluded. Most of the watermarking algorithms have been failed to achieve perceptual transparency and robustness simultaneously because these two requirements are conflicting to each other. The rest options are HLx and LHx. But Human Visual System (HVS) is more sensitive in horizontal than vertical. Hence Watermarking done in HLx region. The attractive feature of DWT is that DWT offers muti resolution representation of image and DWT gives perfect reconstruction of decomposed image.

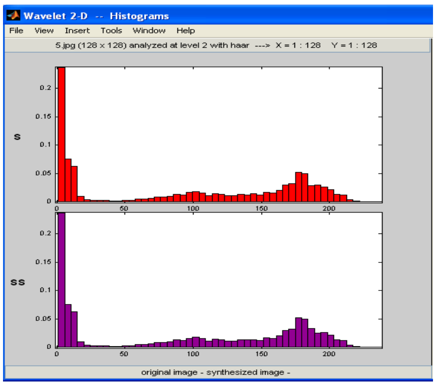


Fig. 6b) Histogram of original and reconstructed images

C. Arnold Transform

Arnold Transform has special property that given image comes to its original state after specific number of iterations. These specific number of iterations termed as 'Arnold Periodicity'. Hence Arnold Transform is used as efficient technique for increasing security in watermarking schemes [6]. The Arnold Transform of image is

$$\begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} (mod\ N) \qquad (3)$$

Where, (x, y) ={0,1,.....N} are pixel coordinates from original image. (x_n,y_n) are corresponding results after Arnold Transform. The periodicity of Arnold Transform (P), is dependent on size of given image. From (7), we have,

x_n=x+y (4)

y_n=x+2*y (5)

If (mod (x_n, N) ==1 && mod (y_n, N) ==1) then P=N.

IV. Our Methodology

The following presented methodology is improvement of algorithm presented in 2008 by Na Li et. al, given in [1].

Basic paper is on conventional DWT based watermarking for general database images, we have improved by increasing levels of security. The extension is done for ROI based medical images.

1. Embedding Algorithm

Steps are watermark embedding process are shown in fig 7 sequentially.

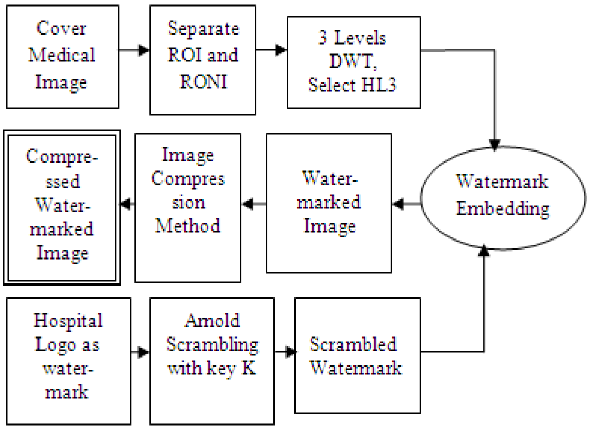


Fig: 7 Watermark Embedding Process

Step 1: Separate ROI interactively from cover medical image. Consider RONI and apply 3 level DWT using 'Haar' wavelet.
Step 3: Select HL3 as shown in fig 5.
Step 4: Find Arnold periodicity 'P' of watermark using (5).
Step 5: Determine key K where $0 \leq K \leq P$. Then generate PN Sequence depending on 'K' and find the sum of random sequence say SUM.
Step 6: If SUM > T where, T is some predefined Threshold value, then find two scrambled images applying Arnold Transform with K1 and K2, where, $K1 = K + Count, K2 = K - Count$, $K + Count \leq P$.
Now, Take absolute difference of two scrambled images to give final 'Scrambled Watermark'.
Step 7: If SUM <T, then apply Arnold Transform directly to watermark image with 'K' to get 'Scrambled Watermark'.
Step 8: Add 'Scrambled Watermark' to HL3 coefficients of cover image as follows:

$$\text{New\_HL3}(i,j) = HL3(i,j) + F * Watermark(i,j) \quad (6)$$

Where, F is weighting factor, New_HL3 (i, j) is newly calculated coefficients of level3, Watermark (i, j) is 'Scrambled Watermark'.
Step 9: Take IDWT at Level3, Level2 and Level1 sequentially to recover RONI part, Now, combine ROI to get 'Watermarked Image'.
Step 10: Compress 'Watermarked Image' to get final 'Compressed Watermarked Image'. This image can be used for transmission through mobile phones or internet.

2. Extraction Algorithm

The proposed method is non blind. Hence the original image is required for extraction process. The simple algorithmic steps are applied are given sequentially.
Step 1: Decompress 'Watermarked Image'. Separate it's ROI and RONI parts. Decompose separated RONI part using DWT at level 3 and consider HL3'.
Step 2: Consider RONI part of Cover image and decompose using 'Haar' wavelet up to 3 levels to get HL3 Coefficients.
Step 3: Apply Extraction formula as follows:

$$Value(i,j) = \frac{abs(HL3(i,j), HL3')}{F} \quad (7)$$

If $Value(i,j) < Threshold_{Value}$
$\quad$ *then* $Extracted\_Watermark(i,j) = 0$
Otherwise $Extracted\_Watermark(i,j) = 1$
Step 4: Perform 'Image Scrambling' using 'Arnold Transform' with key K that we had used in embedding process depending on weather SUM <T to get 'recovered watermark'.

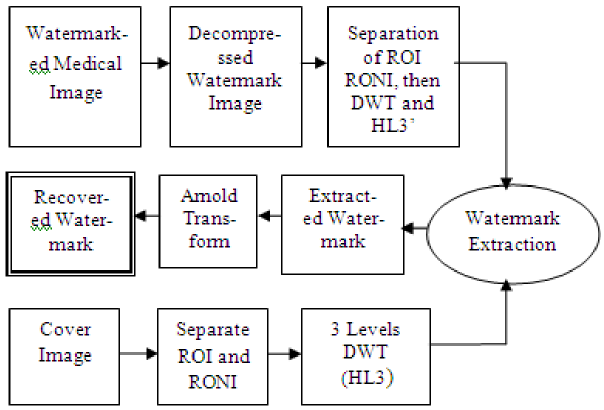


Fig. 8 Watermark Extraction Process

V. Result Discussion

The project is implemented in Matlab and standard database of medical images with 512x512 sizes as cover image and 64x64 size hospital logo as watermark are used for testing. The performance Evaluation is done by two performance evaluation metrics: Perceptual transparency and Robustness. Perceptual transparency means perceived quality of image should not be destroyed by presence of watermark. The quality of watermarked image is measured by PSNR. Bigger is PSNR, better is quality of watermarked image. PSNR for image with size M x N is given by:

$$PSNR(db) = 10log_{10} \frac{(Max_I)^2}{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)-f'(i,j)]^2} \quad (8)$$

Where, f (i, j) is pixel gray values of original image. f '(i, j) is pixel gray values of watermarked image. Max_I is the maximum pixel value of image which is equal to 255 for gray scale image where pixels are represented with 8 bits. Robustness is measured in terms of correlation factor. The correlation factor measures the similarity and difference between original 'watermark and extracted watermark. It'

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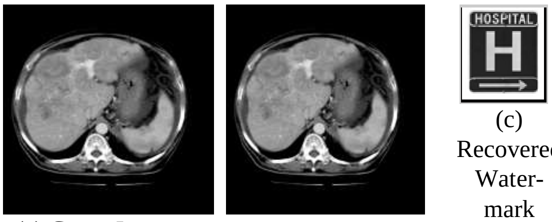
value is generally 0 to 1. Ideally it should be 1 but the value 0.75 is acceptable. Robustness is given by:

$$\rho = \frac{\sum_{i=1}^{N} w_i \, w_i{}'}{\sqrt{\sum_{i=1}^{N} w_i}\sqrt{\sum_{i=1}^{N} w_i{}'}} \quad (9)$$

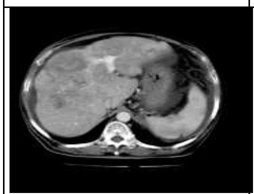
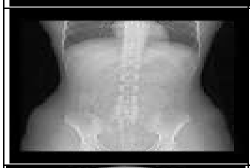
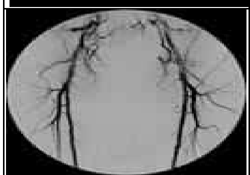
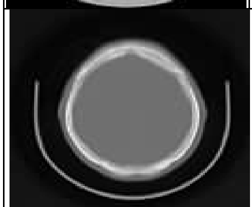
Where, N is number of pixels in watermark, wi is original watermark, wi' is extracted watermark. Here, we are getting PSNR 48.53 dB and ρ=1, for weighting factor F=0.02. The PSNR and ρ for 'standard database of medical images' with corresponding test image and recovered watermarks are shown in Table I.



(a) Cover Image b)Watermarked Image (c) Recovered Water-mark

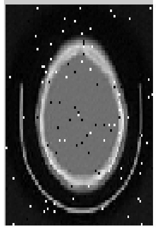
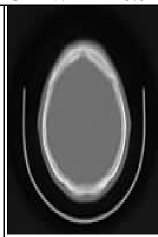
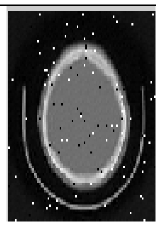
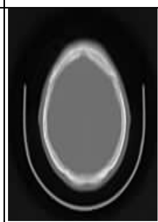
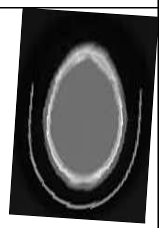
Fig. 9 Cover Image, Watermarked Image, Extracted Watermark

TABLE I
EXPERIMENTAL RESULTS FOR MEDICAL IMAGES WITH SIZE 512 X512

Watermarked Medical Images	Recovered Water-mark	Weighting Factor (F), PSNR(dB), Correlation(ρ)
		F=0.02 PSNR=48.53 Correlation(ρ)=1
		F=0.06 PSNR=42.48 Correlation(ρ)=1
		F=0.03 PSNR=48.46 Correlation(ρ)=1
		F=0.05 PSNR=42.52 Correlation(ρ)=1
		F=0.04 PSNR=48.44 Correlation(ρ)=1

The medical image of 512x512 sizes is tested for various attacks like pepper and salt noise addition, median filtering, wavelet compression, rotation etc given in Table II. Here, we are getting ρ within range of 0.90-0.95 for various attacks. This shows that 'watermark recovery' is satisfactory under different attacks.

TABLE II
EXPERIMENTAL RESULTS FOR VARIOUS ATTACKS ON MEDICAL IMAGE OF 512X512 SIZE WITH F=0.07

Result Image			
Attack	a) Pepper and Salt Noise Addition	b) Median Filtering	c)Wavelet Compression ratio 84.57
PSNR (dB)	31.94	34.87	35.25
Result image			
Attack	d) Noise addition (Gaussian)	e) Median Filtering	f) Rotation attack
PSNR (dB)	30.03	32.64	35.87

VI. CONCLUSION

It is a need of healthcare industry to transmit medical images from one geographical location to other using mobile phones. Improvement in information and communication technologies made it possible to handle such applications through mobile phones. But security is essential factor. This is the strongly robust 'Digital Image Watermarking' with increased security levels and producing exact recovery of original watermark for standard image database, giving correlation factor equals to 1 and PSNR up to 48.53 dBs. Experimental results demonstrate that our technique is very effective supporting more security. As per ISO's norms, the still Image Compression standard JPEG2000 has replaced Discrete Cosine Transform by Discrete Wavelet Transform. This is the reason why more researchers are focusing on DWT, which we have used for implementation. The presented technique provides robustness and high security required for medical images during transmission through internet or mobile phones.

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