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MEDICAL IMAGE WATERMARKING WITH PSNR OPTIMIZATION IN WAVELET DOMAIN BASED ON BAT ALGORITHM

P.V.V.KISHORE, P.DHEERAJ SRIVATHSAV, M.MANIKANTA, N.VENKATRAM, L.S.S.REDDY, GOUTHAM.E.N.D, D.KIMILA DEVI, A.S.C.S.SASTRY

Department of Electronics and Communications Engineering, K.L.University, Guntur.

E-mail: pvvkishore@kluniversity.in, nvenkatram@kluniversity.in, lssreddy@kluniversity.in, dkimila@gmail.com , nishkalmit@gmail.com

ABSTRACT

Medical images communicate imperative information to the doctors about a patient's health situation. Internet broadcasts these medical images to inaccessible sites of the globe which are inspected by specialist doctors. But data transmissions through unsecured web invoke validation problems for any image data. Medical images that are transmitted through the internet must be watermarked with patient pictures for substantiation by the doctors to ascertain the medical image. Medical images contain very susceptible information connected to a patient's health. Watermarking medical images necessitate attentive adjustments to protect the information in the medical images with patient image watermarks. The medical images are used as an envelope image in the watermarking process which is visible on the network. These envelope medical images are watermarked with patient images in wavelet domain there by using the BAT algorithm form optimizing the embedding process for peak signal to noise ratio(psnr) and normalized cross correlation coefficient (ncc) values. The medical image envelope and letter inside envelope i.e. watermark image are transformed into wavelet domain and are mixed using scaling factor alpha which is termed as embedding strength. BAT algorithm is an optimization algorithm specialized in optimizing the values of peak-signal-to-noise ratio for a particular value of alpha, the embedding watermark strength. Finally these watermarked medical images are put on the network along with the secret key that will be used for extraction. At the receiving the embedded watermark is extracted using 2DWT using the embedding strength value using BAT algorithm. The robustness of the proposed watermarking techniques is tested with various attacks on the watermarked medical images. Peak-Signal-to-Noise ratios and Normalized cross correlation coefficients are computed to accesses the quality of the watermarked medical images and extracted patient images. The results are produced for three types of medical images with one patient image watermarks using single key by using four wavelets (haar, db, symlets, bior) at four different levels (1&2).

Keywords: *Medical Image Watermarking, Discrete Wavelet Transform (DWT), Optimization algorithms, BAT algorithm, MRI, CT and Ultrasound Images, psnr and ncc*

1. INTRODUCTION

Watermarking digital multimedia [1]-[4] contents has grown rapidly in the recent past with the advances in internet technology. This watermarking functionality is to hide information, protect digital copyrights and for content identification of multimedia contents exchanged over the internet. Internet data travels through unprotected routing switches all over the world. Hence watermarking comes to the rescue for protecting multimedia data that is transmitted through these unsecured servers.

Medical image watermarking [5]-[8] functions significantly in supporting a patient by conveying his infirmity using medical images through unsecured networks such as the internet to expert doctors around the world. This practice helps to expand the possibility of distantly stationed patients where no expert medical doctor is accessible to increase their probability of endurance.

Trafficking medical images through unsecure internet is prone to unwelcomed modification to the sensitive contents of the medical images. Medical images contain vulnerable information which is valuable related to the health of the patient. Medical

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practitioner has to take supreme care to check that the images are not meddled with, before analysing the medical images downloaded from the unsecured internet. For this reason, authentication of medical images such as Ultrasound scans, MRI scans, x-ray and Computer Tomography (CT) scans has to be watermarked. The host medical image can be watermarked with patient information before transmitting on the internet. At the physician's end it has to de watermarked before proceeding for diagnostics.

Medical cover images are watermarked with patient image as watermark which forms an invisible detection code. A medical image watermarking is a perfectly hidden watermarking pardigrams as proposed by [9]. The application of medical image watermarking is towards telemedicine. In recent years medical image watermarking is primarily used to hide patient information such as patient's name, age, gender which can uniquely identify a patient by [10]. This patient related watermark information is extracted to determine the authenticity of the medical images. As the extracted watermark from the medical image matches the patient data in the doctor's office, it is proved that these medical images belong to a particular patient in [11].

There is a growing demand for applications related to watermarking due to the ever increasing storage and sharing of digital media contents around the world on the internet. Watermarking has invaded every multimedia transmission on the internet such as text documents [12], images [13] and even audio [14] and video data watermarking [15]. Various digital image watermarking schemes are proposed and implemented successfully by researchers around the world in an image's spatial domain [16], transform domain [17] along with encryption techniques which as robust [18], semi-fragile[19] and some are fragile watermarking schemes.

The growing need for medical image watermarking schemes is due to the usage of internet to transfer medical images among expert doctors for advices and case studies. Medical images can and are saving human lives around the world. But with sharing comes the fear of hackers. Hackers attack these medical images modifying their details making the medical image data misleading to a doctor. This point can be better proved by looking at the original and modified medical images as shown in figure 1 and figure 2.

Figures 1(a) is the original MRI image of a patient. When a doctor at a remote location wants a second opinion about the disease, he transmits it to another expert through internet. Figure 1(b) shows the modified medical image by the hackers. This kind of modifications can sometimes cost a human life. Here there is a need to prevent medical data from hackers and prove the authenticity of the medical images at the receiving doctor's end. Figure 2 shows the original and attacked CT brain image.

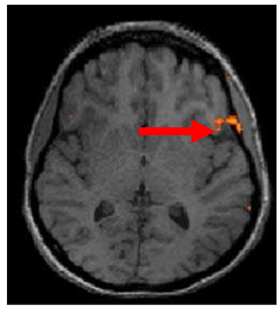

Figure .1(a). *Original MRI Brain image Transmitted to the Doctor through internet*

Figure. 1(b). *Hacked MRI Brain image Transmitted to the Doctor through internet*

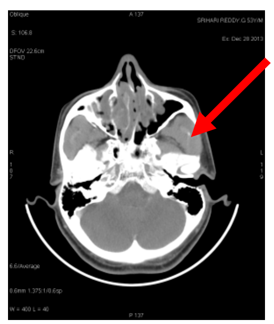

Figure. 2(a). *Original CT Brain image Transmitted to the Doctor through internet*

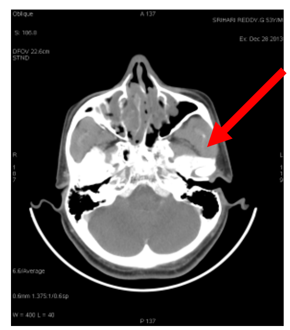

Figure. 2(b). *Hacked CT Brain image Transmitted to the Doctor through*

Coatrieux et al [20] enlightened that digital watermarks should be considered as a security tool in order to protect medical records. Giakoumaki et al [21] proposed a wavelet transform-based watermarking, which fulfills the strict requirements concerning the acceptable alterations of medical images. The proposed scheme embeds numerous watermarks helping diverse functionality such as authentication containing doctor's digital signature as a robust watermark, patient's personal and examination related data and a fragile watermark for data integrity control. Thus, they state that the watermarking tool offers alternatives for different issues associated with medical data management and distribution. This research paper proposes to

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find which wavelets are better for watermarking medical images and up to what level of decomposition will result in perfect watermarked image.

Irany et al [22] proposes a high capacity reversible multiple watermarking scheme for medical images based on integer-to-integer wavelet transform and histogram shifting. The novelty of the proposed scheme is that it uses a scalable location map and incorporates efficient stopping conditions on both wavelet levels and different frequency sub bands of each level to achieve high capacity payload embedding, high perceptual quality, and multiple watermarking capabilities. Results show that the proposed method attains high perceptual quality in high capacity rates for the medical images.

Lavanya et al [23] proposed non region of interest (NROI) based medical image watermarking schemes, where the patient details are embedded in non-ROI region of an image. The encrypted image is divided into non overlapping tiles to identify region of interest and non-region of interest. In examination site examiner embeds patient details in non-ROI [24] of encrypted image using a data-hiding key. With an encrypted image containing patient details, a receiver may first defile and decrypt it using the encryption key, and the decrypted version is similar to the original image.

Wakatani et al [25], proposes a digital watermarking technique by shunning the deformation of the image data in ROI by embedding watermark into areas other than the ROI. Watermark image is compressed by a progressive coding algorithm which is used as the signature information. The proposed method can detect the signature image with moderate quality from a clipped image including the ROI. Furthermore, by dividing the contour of the ROI into several regions and embedding the signature information in the regions respectively, the signature image with moderate quality can be acquired from a clipped image including only part of the ROI.

Eswaraiah et al [32] proposed a Region of Interest (ROI) and Least Significant Bit (LSB) based fragile watermarking technique for tamper detection and recovery of medical images. At first, medical image is divided into ROI and NROI. Later, authentication information is inserted into ROI and recovery information into NROI. To increase embedding capacity in ROI, authentication information is compressed using Run Length Encoding (RLE) technique before inserting into ROI. Experimental results reveal that any tampering to ROI of medical image is identified and recovered without any loss.

By using the reduced difference expansion method, we can embed a large amount of data in a medical image whose quality can also be maintained. Moreover, the original image can be restored after extracting the hidden data from the stegno image. Experimental results show that the proposed scheme provides higher embedding capacity at the same level image quality compared with Tai's [33] difference expansion method.

This research proposes to use wavelet transform and BAT algorithm proposed by X.-S. Yang and Xin-She Yang [26]-[27] for medical image watermarking. The medical image is transformed into wavelet domain using a 2D DWT [29]-[30]. The type of mother wavelet and level of scaling are two parameters that are of interest to look for while applying the algorithm. Watermark in this case is a patient image. This patient image is embedded into the medical cover image in transform domain. The extraction process is an inverse algorithm to embedding process. From the watermark embedding and extraction process two performance parameters are computed in the form of peak-signal-to-noise ratio (psnr) and normalized cross correlation (ncc). This procedure of watermarking gives unpredictable outcomes for medical images as cover images with out of bounds psnr and ncc values. These unpredictable results of watermarking algorithm can be controlled using optimization algorithms such genetic algorithm (GA), particle swarm optimization (PSO) and ant colony optimization (ANO). This research uses BAT algorithm for optimizing the psnr and ncc values during watermark embedding and extraction process[34]-[35]. The results of simulation show a better performance of BAT algorithm over GA and non-optimization watermarking process for medical images with patient image as watermark [31].

The rest of the paper is organized as follows. Section 2 gives a brief introduction of discrete wavelet transform and BAT algorithm. Section 3 deals with the process of watermarking. Section 4 gives medical image dewatermarking algorithm. Results and discussion in section 5 present insights into the use of multiresolution wavelet transform with BAT for medical image watermarking. Finally conclusions are made on the medical image watermarking procedures in section 6.

2. WAVELET THEORY AND BAT ALGORITHM

This research proposes the use of two most popular techniques used in data encryption and

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image processing in computer communications for copyright protection. The watermarking of the encrypted patient image watermark into a medical image is accomplished using 2D discrete wavelet transform. The amount of watermark required for producing an information preserving watermark is done using optimizing the values of psnr and ncc with the help of BAT algorithm. This section provides the basics of DWT and BAT algorithm used for medical image watermarking.

2.1 Discrete Wavelet Transform

This is Wavelet transform is applied to decompose a medical image $I^{Mi}(x,y)$ into various levels of abstraction $\left\{\varphi^{A},\varphi^{H},\varphi^{V},\varphi^{D}\right\}$ and can be reconstructed perfectly with fewer number of wavelet coefficients without compromising on visual quality in P.V.V.Kishore et al (2011, 2012, 2012). The structure of Wavelet transform provides an multilevel decomposition on images, with each level corresponding to a lesser resolution compared to the previous level as shown in figure 3.

This multi resolution analysis of 2D DWT permits to decompose an image into approximate and details coefficients. The 2D discrete wavelet transform divides the image into low frequency (L) and high frequency components (H) at level1 using 4 decomposition filters{LL_D, LH_D, HL_D, HH_D}.

The 2D medical image $I^{Mi}(x,y)$ passes through low pass filter and a down sampler of level 2 to produce approximate image at level-1 wavelet decomposition. Similarly 2D medical image $I^{Mi}(x,y)$ is applied to a high pass filter and down sampler to create detailed image at level-1 wavelet decomposition.

Further in level2 decomposition the low frequency information is again divided into four LL, LH,HL and HH coefficients. The high frequency detailed components in level1 are intact. The second level decomposition also uses same set of decomposition filters as level-1. The wavelet decomposition process is shown in the figure 3. The notion $L^2(R^2)$, where R is a set of real numbers, denote the finite energy function $I^{Mi}(x,y)$ in R^2; and *x,y* in R. In two dimension wavelet transform, a 2D scaling function $\varphi(x,y)$, and three two dimensional wavelets, $\varphi^{H}(x,y)$, $\varphi^{V}(x,y)$ and $\varphi^{D}(x,y)$ are produced as shown in figure 3.

The above functions represent gray level variations along different directions such as horizontal variations, vertical variations and diagonal variations. The DWT of $I^{Mi}(x,y)$ of size $M\times N$ is

$$W_{\varphi}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}I^{Mi}(x,y)\varphi(j_0,m,n) \quad (1)$$

Where j, m, n, M, N are integers, i= {H, V, D}, j_0 is an arbitrary starting scale and the coefficients W_{φ} define an approximation of f at scale j_0.

$$W_{\varphi}^{i}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}I^{Mi}(x,y)\psi_{j,m,n}^{i} \quad (2)$$

The coefficients in the above equation add horizontal, vertical and diagonal details as shown in figure.3.8 for scales $j\geq j_0$. The $\varphi_{j,m,n}$ and $\psi_{j,m,n}^{i}$ denote scaled and translated basis functions as shown below,

$$\begin{aligned}\varphi_{j,m,n}(x,y)&=2^{j/2}\varphi(2^{i}x-m,2^{j}n-1)\\ \psi^{i}{}_{j,m,n}(x,y)&=2^{j/2}\psi^{i}(2^{i}x-m,2^{j}n-1)\end{aligned} \quad (3)$$

Given W_{φ} and W_{ψ}^{i}, $I^{Mi}(x,y)$ is obtained via inverse DWT as:

$$I_{Mi}^{W}=\frac{1}{\sqrt{MN}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left(W^{j_0}\varphi_{j_0}+\sum_{i}\sum_{j=j_0}^{\infty}W_{\psi^{i}}^{j}W_{j}^{i}\right) \quad (4)$$

Eq.4 produces a watermarked medical image in spatial domain.

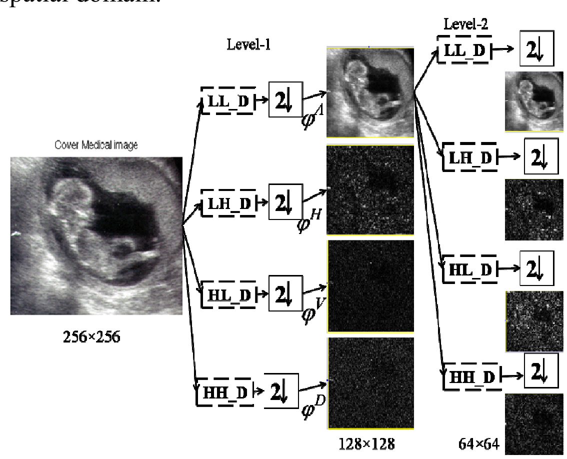

Figure. 3. *Wavelet Decomposition of an Ultrasound Medical based on 2D Filter Discrete Wavelet Transform*

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2.2 BAT Algorithm

BAT algorithm is a heuristic search and optimization algorithm based on echolocation behavior of bats was proposed by Xin-She Yang[26]. Bats use sonar type of processing called, echolocation, to locate prey, to avoid obstruction and navigate through the dark nights. Bats listen to the echo's that are received from the surrounding objects by transmitting a very loud sound pulse. Different species of bats use sound pulses with different properties such as short frequency modulated sound pulses or constant frequency sound pulses. This echolocation behavior of bats is devised to optimize a given objective function as proposed by Xin-She Yang[26] is called BAT Algorithm(BA).

The starting point in BAT based optimization algorithm is to define a objective function $f(x)$. Initialize a few parameters such as bat population $x^i\,(i=1 \text{ to } n)$ and initial velocities of bats v^i. Initialize pulse frequency f^i at x^i. Pulse frequency can vary in the range $f^i \in \left[0, f^{\max}\right] \forall i = 1 \text{ to } n$. For a particular optimization function the solution space can be adjusted by selecting frequency range close to sphere of interest. Finally initialize pulse rate γ^i and loudness $L^i \;\forall i \in \Im$. By selecting iterations itr to a specific count, new solutions are generated by adjusting the frequencies.

This means the bats try to reach their target location by adjusting their frequencies and computing their velocities and locations at each new frequency. This computation can be mathematically modeled as

$$f^i = f^{\min} + \left(f^{\max} - f^{\min}\right)\mu \tag{5}$$

Where $\mu \in [0,1]$ is a uniformly distributed random vector.

$$v^i_{itr} = v^i_{itr-1} + \left(x^i_{itr} - x^*\right) f^i \tag{6}$$

Where v^i_{itr-1} is the initial velocity of the bat population. x^* is the current global best solution ,i.e. location of the target which is located after comparing all the solutions among all the n bats. The final or next best location of the target can be updated using the following mathematical model

$$x^i_{itr} = x^i_{itr-1} + v^i_{itr} \tag{7}$$

From equation(7) it can be seen that the location or solution space is updated with the bat updated velocity in each iteration v^i_{itr}. v^i_{itr} in turn is derived from bat frequencies or wavelengths as $v^i_{itr} = f^i_{itr} \times \lambda^i \; or \; f^i \times \lambda_{itr}{}^i$. Initially bat frequencies are randomly allocated between $[f^{\min}, f^{\max}]$, which can be chosen based on the objective function that is being minimized.

The above process provides a solution space containing global best positions of the 'n' bats target. A local best solution can be generated locally for each bat using random walk

$$x^n = x^o + \eta L^{itr} \tag{8}$$

x^n is the new location or solution space that is produced from x^o, the old global solution space using a loudness updation factor with a random constant $\eta \in [-1,1]$. Further updation of loudness L^i and pulse rate γ^i are done between iterations. L^{ini} initial loudness can be set as 1 and the final loudness that is to be reached is set as $L^{fin} = 0$ indicating that the bat has finally reached its target where it stops temporarily its search process.

The new loudness factor can be mathematically modeled as

$$L^i_{itr} = \kappa L^i_{itr-1} \tag{9}$$

Where κ is a constant. The pulse rate is updated as

$$\gamma^i_{itr} = \gamma^i_0 \left[1 - e^{-\rho(itr)}\right] \tag{10}$$

Where ρ is a constant. For our experimentation both the defined constants are given values ranging from 0 to 0.7 based on various medical cover images used for watermarking. A series of experiments are to be conducted to fix the values of loudness L^i_{itr} and pulse rate γ^i_{itr}. For watermarking simulations using medical images as cover images the value of loudness varies $L^i_{itr} \in [0.5, 1.5]$ and pulse rate $\gamma^i_{itr} \in [0.2, 0.5]$.

3. WATERMARK EMBEDDEDING

Watermarking is wavelet domain is not new to researchers. Our previous work N.Venkatram et al [17], used discrete wavelet transform to watermark medical images. Figure 4 shows the watermarking technique used by N.Venkatram et al [18]. This medical image watermarking using wavelet transform is modified in this research paper as shown in figure 5. The modification is proposed using BAT algorithm to optimize the values of psnr and ncc to produce a good embedding strength for the watermark. Our technique is very robust to

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attacks which will be demonstrated using simulations in section 5.

Medical Images of standard resolution 256×256 are watermarked with their analogous patient image as watermark of slightly lower resolution of 64×64 using the following steps.

S1. Carry out n^{th} level 2D Discrete Wavelet Transform (DWT) on the Medical Image (Cover Image) (N.Venkatram et al (2014)) and decompose in to following sub-bands (LL, LH, HL, HH). Where n is the number of levels a wavelet is supposed to be decomposed. In our research we tried with four different levels i.e. n=1, 2, 3 and 4.

S2. The watermark is embedded using the formula

$$W(i,j) = W^{Sub}(i,j) + (2\sigma + \lambda)(2w^{e}(k) - 1) \qquad (11)$$

Where $W(i,j)$ is watermarked medical image with encrypted patient image. $W^{Sub}(i,j)$ is n^{th} level wavelet subbands of medical image. σ is the ratio of standard deviation of wavelet coefficient block and the maximum standard deviation of all the coefficient blocks. λ is the fixed embedding watermark strength which will be found using BAT algorithm in this paper. $w^{e}(k)$ is the encrypted patient image at k^{th} position.

S3. Assemble all the modified sub-bands and apply inverse 2D Wavelet Transform (IDWT) and is formulated as

$$I^{WMi} = \left(W^{(n)}\right)^{-1} \qquad (12)$$

Where 'n' represents 4 sub-bands for n=1, LL, LH, HL, HH. is the watermarked medical image. The watermarked medical image I^{WMi} is obtained which contains patient image as watermark.

S4. Compute embedded psnr and ncc values using the watermarked medical image and original medical image from equations 14 and 15 in sec 5.

S5. Initialize BAT algorithm parameters as discussed in section 2.2. The value of λ is estimated using BAT algorithm. Psnr and ncc are used as objective functions for optimization. Psnr should have a minimum value and ncc should have a maximum value less than 1. Proposed watermarking is shown in figure 5.

BAT algorithm returns value of λ by optimizing the values of psnr and ncc for embedding the patient image watermark into the medical cover image. The value of λ is updated in every iteration till optimum values of psnr and ncc are not reached. The only constraint in using an optimization technique for medical image watermarking is the time for simulation, which in this case is achieved with iterations ranged as $itr \in [15,36]$.

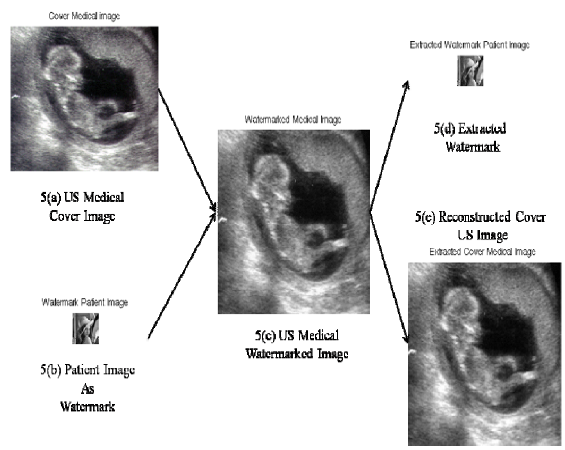

Figure. 4. *Medical Image Watermarking in Wavelet Domain*

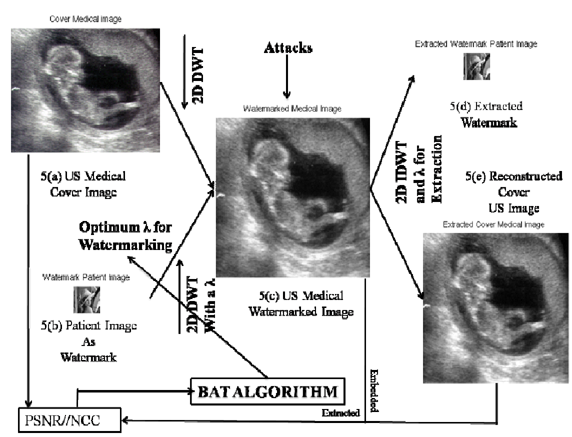

Figure.5. *Proposed Medical Image Watermarking in Wavelet Domain using BAT Algorithm*

4. WATERMARK EXTRACTION PROCESS

The watermarked medical image I^{WMi} is sent distantly through unsecured internet servers to expert medical doctors from remote parts of the world. At the doctor's place the system decouples the attacked watermarked medical image form the watermark for authentication. The following extraction process is incorporated at the doctor's

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side to extract the encrypted watermark patient image and decrypt the patient watermark image.

S1. The possibly attacked watermark medical image is treated with 2D discrete wavelet transform (DWT) and decomposed to n^{th} level with n sub-bands LL, LH, HL and HH.

S2. Medical image is decoupled from the patient watermark image using the inverse expression

$$I^{ep}(x,y) = \frac{2(W^{RMi}(i,j) - W^{Mi}(i,j))}{(2\sigma+\lambda)+1} \tag{13}$$

Where $W^{RMi}(i,j)$ is transformed the received watermarked medical image at i^{th} and j^{th} location. $W^{Mi}(i,j)$ is the sub bands of original cover image that is received with the transmitted watermarked image. $I^{ep}(x,y)$ is the recovered watermark patient image .

S3. Extracted watermark is a patient image which again is accomplished using a precise value of λ. This λ value is estimated using BAT algorithm by computing values from extracted psnr and ncc objective functions. An optimum value of λ is obtained for extraction of watermarked medical images. Finally authentication of the medical image is identified by extracted patient image.

5. RESULTS AND DISCUSSION

The proposed watermarking method is put into operation on MATLAB 13.0.1 software with three different types of medical images which are considered as cover images. MRI, CT and Ultrasound medical (US) images are used as cover images of standard resolution 256×256. Watermark is a patient image of resolution 64×64. Since medical images are gray scale images, it is intended to consider grayscale patient image as watermark. The dynamic standard deviation ratio factor σ is used for watermarking in our experiments which is computed from wavelet coefficients. The other scaling factor λ is estimated using BAT algorithm. The estimation of optimum embedding strength λ, for minimum value of psnr and maximum value of ncc is used to embedded the patient watermark in the medical cover image.

The performance of the proposed medical image watermarking is judged by computing peak signal to noise ratio (psnr) and normalized cross correlation coefficient (ncc). These parameters will decide the robustness of the watermarking method using DWT watermarking process by most of the researchers. Watermarking of medical images is relatively susceptible process as the medical images contain information related to life changing scenarios of human subject. Corruption of the original medical image by watermarking process should be within the acceptable confines of human perception. The visual sensitivity of the watermarked and extracted images is mathematically represented by calculating psnr and ncc. The values of psnr and ncc values are refined using BAT algorithm to produce a watermarked medical image that exactly mimics the original medical image before watermarking.

5.1 Embedded Peak Signal to Noise Ratio (psnr)

Embedded psnr [31] is the measure of peak error between original image and watermarked image and is computed using the following expression where N and M represent image resolution. $I^M(x,y)$ is the original medical image and W^{Mi} is the watermarked medical image. psnr is the peak signal to noise ratio in db which range between 40db to 60 db generally for good watermarking.

$$psnr = 10\log_{10}\left(\frac{MN\left(\max(\max(I^M(x,y)\right)^2}{\sum_{x\in N}\sum_{y\in M}\left(I^M(x,y) - W^{MI}\right)^2}\right) \tag{14}$$

5.2 Extracted Normalized Cross Correlation Coefficient (ncc)

Normalized cross correlation [31] is mostly used by pattern recognition research for measuring similarity between a query image and the images from the database. The cross correlation is normalized by subtracting the mean and dividing by standard deviation. Embedded normalized cross correlation coefficient gives the measure of closeness between watermarked image and original medical image.

$$ncc = \frac{\sum_{x\in N}\sum_{y\in M} I^M(x,y)\times W^{Mi}(x,y)}{\sqrt{\sum_{x\in N}\sum_{y\in M}\left[I^M(x,y)\right]^2}\sqrt{\sum_{x\in N}\sum_{y\in M}\left[W^{Mi}(x,y)\right]^2}} \tag{15}$$

The values of normalized cross correlation coefficients (ncc) range from 0 to 1. Larger values of ncc are preferred for better watermarking.

Figure 6 shows a patient's skull CT along with its 2D discrete wavelet transform. 2D DWT decomposes the medical image using 'db2' mother wavelet to level-1 decomposition. All the medical

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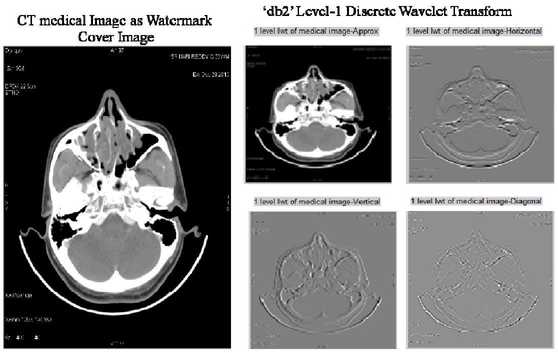
images used in this research are acquired from radiology department of NRI medical college and Hospital at Guntur, Andhra Pradesh, INDIA.

Figure 6(a) shows original brain CT image of a patient. Figure 6(b) shows a decomposed CT medical image using 'db2' wavelet.



. (a) (b)

Figure.6. Discrete Wavelet Transform of Level -1 using 'db2' mother wavelet (a) Original skull CT Medical Image (b) and its 2D DWT

CT brain medical image (256×256) is used as cover image for watermarking in figure 7(a) and Lena image is used as patient image (64×64) in figure 7(b). DWT-BAT watermarking procedure proposed in this research embeds watermark patient image into brain CT cover image to produce a watermarked medical image as shown in figure 7(c). Figure 7(d) shows the extracted watermark of patient image. Visually figure 7 shows that the watermarked image and extracted image match powerfully as per human visual system.

Figure 7 shows the robustness of DWT-BAT algorithm. Similar results are acquired using MRI brain image, figures 8 and 9, and Ultrasound (US) Medical images, figures 10 and 11 as cover images.

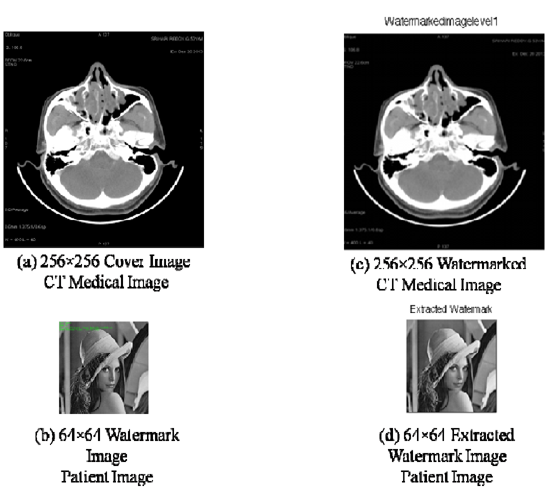
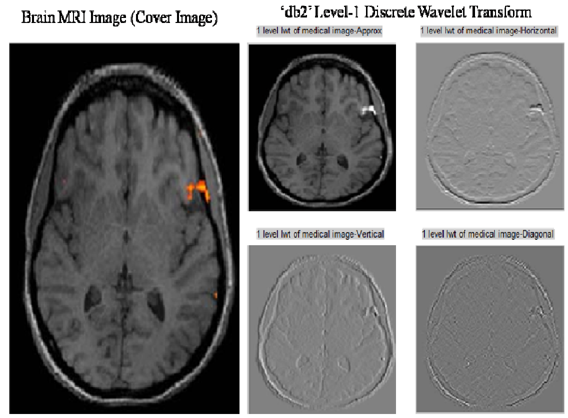


Figure.7. (a) Brain CT Cover Image (b) Watermark Patient Image (c) CT Watermarked Medical Image (d) Extracted Watermark patient image



(a) (b)

Figure.8. Discrete Wavelet Transform of Level -1 using 'db2' mother wavelet (a) Original Brain MRI Medical Image (b) its 2D DWT

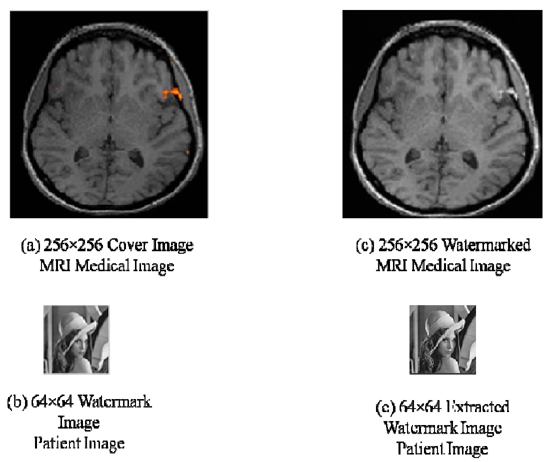


Figure 9: (a) MRI Brain Cover Image (b) Watermark Patient Image (c) MRI Watermarked Medical Image (d) Extracted RSA Encrypted Watermark (e) Decrypted Watermark patient Image with KEY

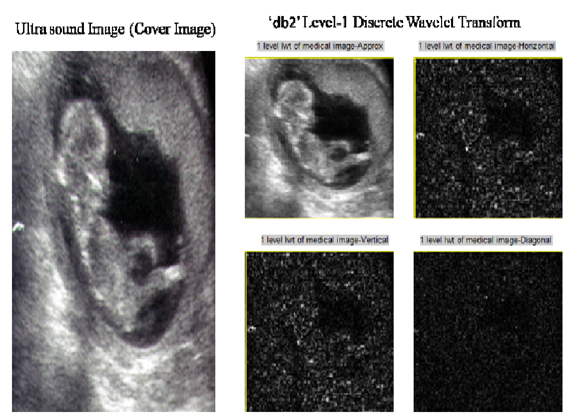


Figure.10. Discrete Wavelet Transform of Level -1 using 'db2' mother wavelet (a) Original pregnant ultrasound (US) Medical Image (b) its 2D DWT

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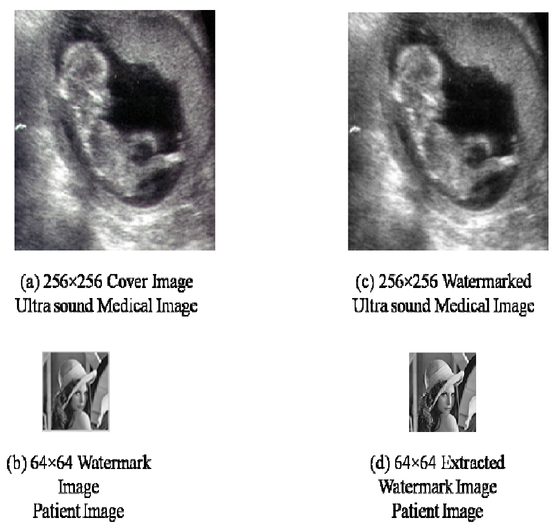

Figure.11. *(a) Pregnant US Cover Image (b) Watermark Patient Image (c) US Watermarked Medical Image (d) Extracted Watermark*

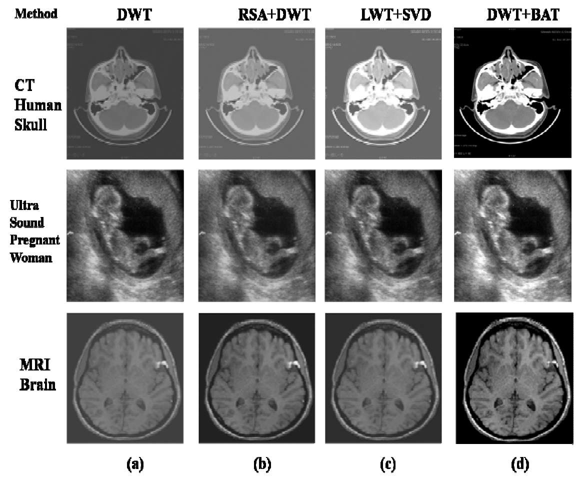

Figure.12. *Visual Comparison of (d) DWT-BAT with three other medical image watermarking methods used by us previously (a) Only DWT (b) RSA-DWT (c) LWT-SVD*

Table 1. Embedded Psnr And Ncc For Medical Cover Images For Various Watermarking Methods

Watermarking Method	**DWT**		**RSA-DWT**		**LWT-SVD**		**DWT-BAT**	
Cover Medical Image	**PSNR (db)**	**NCC**	**PSNR (db)**	**NCC**	**PSNR (db)**	**NCC**	**PSNR (db)**	**NCC**
MRI	49.8998	0.9252	46.9433	0.9435	44.8228	0.9735	30.0101	0.9989
CT	48.3565	0.9211	45.5453	0.9523	43.3435	0.9623	30.0211	0.9987
Ultrasound(US)	46.3454	0.9112	44.2344	0.9312	42.3544	0.9412	31.0010	0.9899

From figure 11(c) it can visually be observed that the watermarking process proposed in this paper has actually removed noise from the ultrasound image. At this point we want to highlight the use of optimization technique such as BAT algorithm for watermarking. Figure 12 shows the comparison of DWT-BAT proposed in this research to other watermarking techniques used by us [17][18][31] for medical image watermarking.

Performance of the watermarking methods is also formulated using equations 14 and 15 in Table-I for the embedded watermark and original medical image for all three different medical images. The values are computed for all our previously accomplished methods. The data analysis highlights the effectiveness of the DWT-BAT watermarking method for medical image watermarking with patient image as a payload.

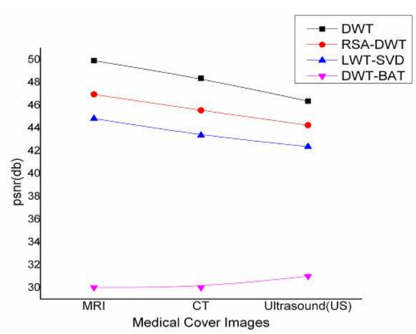

Figure.13. *Comparison graph for watermarking methods with DWT-BAT using embedded psnr values*

Performance plots using embedded psnr and ncc are plotted from table-1 in the figures 13 and 14 respectively. From the graphs it can be confirmed that DWT-BAT outperforms the other watermarking methods using medical images of various types.

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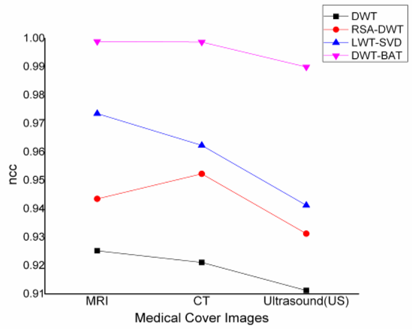

Figure.14. Comparison plot for watermarking Methodswith DWT-BAT using ncc values

The performance analysis for extraction of watermark and the quality of medical cover image are very similar to that of embedding process for all the watermarking methods. In the extraction process also there is a clear distinction shown by DWT-BAT watermarking algorithm which outperformed all other methods.

Computing normalized cross correlation coefficient form equation 15 for the extracted watermark patient images reveals the performance of the RSA-DWT medical Image watermarking process. The values are put up in Table-2

The watermarked medical images are transmitted through unsecured networks and are most likely to be attacked from various unlawful hackers. Hence to test the robustness of the watermarking method proposed in this paper, various attacks are simulated. The total number of attacks simulated for testing our DWT-BAT proposed watermarking algorithm is 12.

Generally the ncc coefficient for better watermark is something above 0.75[16]. For remarkably excellent correlation the value of ncc should be around 0.9999 or 1. A value of zero for ncc indicates a complete uncorrelation between the original cover image and the watermarked image. Table-2 ncc values are computed for 'db2' wavelet at level-1 of watermarked image.

The watermarked medical image is subjected to twelve attack categories such as a 3×3 window mean filtering, a 3×3 window median filtering, 45˚, 90˚, 135˚ and 180˚ rotation, Gaussian noise and salt & pepper noise of noise densities 0.001,0.005,0.01 and 0.1, shear attack with [x=1,y=0] and finally crop with crop area [100,100]. Table-2 shows the robustness of DWT-BAT under these attacks. Plotting the extracted ncc values of the patient image watermark for various techniques with three sets of medical cover images will reveal the extraordinary quality of watermarks produced by proposed DWT-BAT watermarking algorithm.

Figure 15 plots ncc values of extracted patient image watermarks for 4 watermarking procedures against attacks with MRI cover images. Similar plots are produced in figures 16 and 17 for CT and US medical cover images. Finally figure 18 shows the dynamic range variations in extracted watermark ncc values for three medical cover images in four different watermarking algorithms.

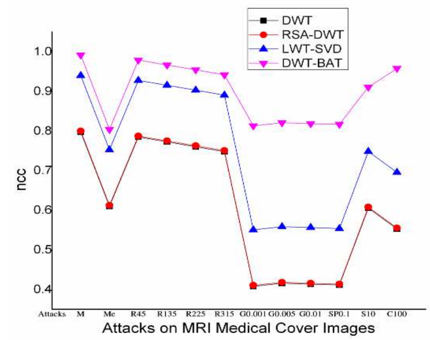

Figure.15. Plot showing Extracted ncc values for MRI Medical cover images against various attacks for 4 watermarking algorithms

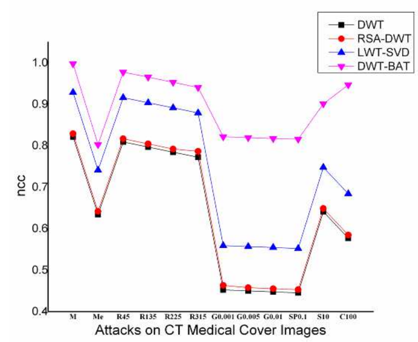

Figure.16. Plot showing Extracted ncc values for CT Medical cover images against various attacks for 4 watermarking algorithms

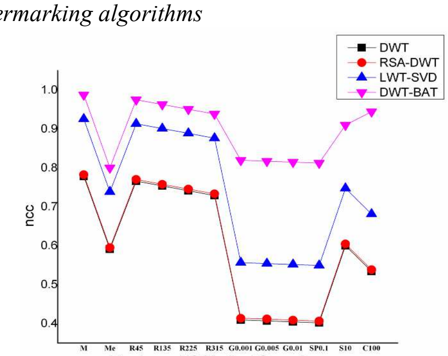

Figure.17. Plot showing Extracted ncc values for US Medical cover images against various attacks for 4 watermarking algorithms

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Table 2. *Comparison of Extracted watermarks*

Cover Images	Attacks	Mean Filtering	Median Filtering	Rotation (45˚)	Rotation (135˚)	Rotation (225˚)	Rotation (315˚)	Gaussian Noise (0.001)	Gaussian Noise (0.005)	Gaussian Noise (0.01)	Salt & Pepper Noise(0.1)	Shear [x=1,y=0]	Crop(100,100)
DWT	**MRI**	0.7971	0.6098	0.7848	0.7725	0.7602	0.7479	0.4079	0.4156	0.4133	0.4114	0.6055	0.5528
	CT	0.8215	0.6342	0.8092	0.7969	0.7846	0.7723	0.4523	0.45	0.4477	0.4454	0.6409	0.5772
	US	0.7782	0.5909	0.7659	0.7536	0.7413	0.729	0.409	0.4067	0.4044	0.4021	0.6	0.5339
RSA-DWT	**MRI**	0.7997	0.6124	0.7874	0.7751	0.7628	0.7505	0.4105	0.4182	0.4159	0.4136	0.6081	0.5554
	CT	0.8292	0.6419	0.8169	0.8046	0.7923	0.7865	0.4634	0.4577	0.4554	0.4531	0.6486	0.5849
	US	0.7825	0.5952	0.7702	0.7579	0.7456	0.7333	0.4133	0.4117	0.4087	0.4064	0.6043	0.5382
LWT-SVD	**MRI**	0.9398	0.7525	0.9275	0.9152	0.9029	0.8906	0.5506	0.5583	0.5564	0.5537	0.7482	0.6955
	CT	0.9284	0.7411	0.9161	0.9038	0.8915	0.8792	0.5592	0.5569	0.5546	0.5523	0.7478	0.6841
	US	0.9256	0.7383	0.9133	0.901	0.8887	0.8764	0.5564	0.5541	0.5518	0.5495	0.7474	0.6813
DWT-BAT	**MRI**	0.9918	0.8037	0.9787	0.9664	0.9541	0.9418	0.8129	0.8206	0.8183	0.8168	0.9105	0.9578
	CT	0.9978	0.8027	0.9777	0.9654	0.9531	0.9408	0.8219	0.8196	0.8173	0.8158	0.9012	0.9468
	US	0.9876	0.8003	0.9753	0.963	0.9507	0.9384	0.8195	0.8172	0.8149	0.8126	0.9101	0.9444

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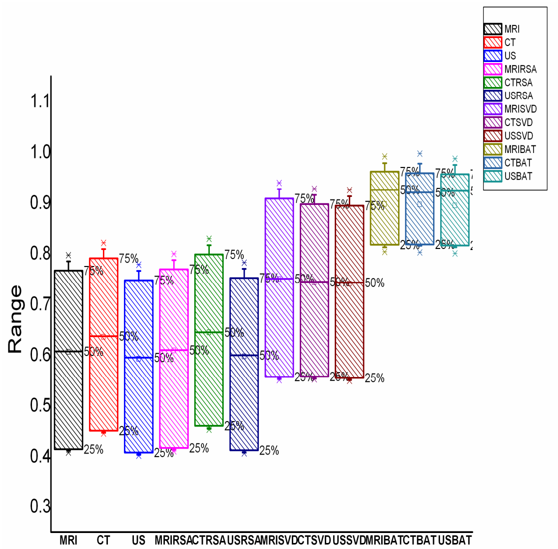

Figure.18. Box plot showing dynamic range of extracted watermark ncc values

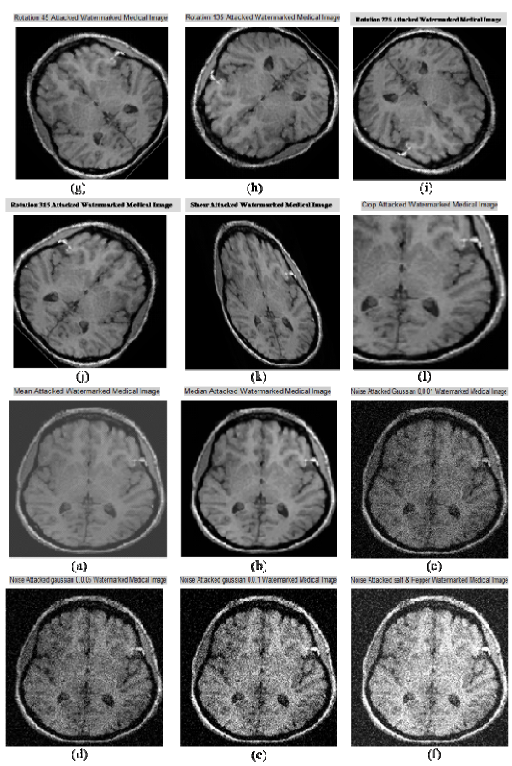

Figure.19. *Attacked watermarked MRI Images(a)Mean (b) Median (c)Gaussian Noise(.001) (d) Gaussian Noise(0.005)(e) Gaussian Noise(.01) (f) Salt & Pepper Noise(.001) (g) Rotation (45^0) (h) Rotation (135^0) (i) Rotation (225^0) (j) Rotation (315^0) (k) Shear attack(x-1,y=0) (l) Crop attack (100,100)*

From the box plot of figure 18, it is observable that the extracted ncc values for the proposed DWT-BAT watermarking algorithm have produced a small dynamic range compared to our previously simulated watermarking algorithms under attacks for medical image watermarking. This shows that the proposed DWT-BAT watermarking for medical images can withstand attacks and reproduce better quality extracted watermarks. Visual analysis of the attacked watermarked images with their extracted medical cover images and watermark patient images are shown in figures 19-24 for three types of medical cover images i.e. MRI, CT and US respectively.

Figure.20. *Extracted Patient images from US Watermarked Images with 'db2' after (a) 3×3 window mean attack,(b) median attack,(c)-(f) rotation attacks,(g)-(j) noise attack, and (k) shows shear attacks and (l) crop attacks*

From figures 19,21 and 23, it can be observed that the attacked watermarked medical images using dwt-bat algorithm produces remarkably good medical images without loss of information related to patients health . The watermarked medical images after attacks are very close to original medical images in both visual quality and quantitatively using psnr and ncc values from table-2. Similarly extracted watermark patient images from attacked watermarked medical images with proposed DWT-BAT algorithm are of good quality as shown in figures 20, 22 and 24.

This DWT-BAT watermarking algorithm was tested for various decomposition levels of discrete wavelet transform and various mother wavelets.

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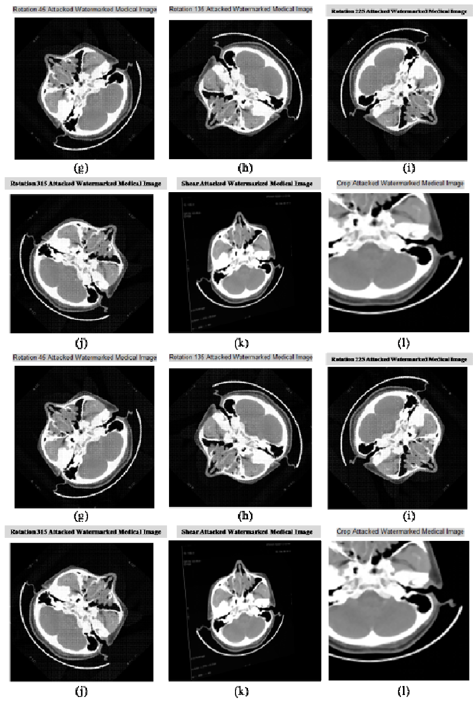

Figure.21. Attacked watermarked CT Images(a)Mean (b) Median (c)Gaussian Noise(.001) (d) Gaussian Noise(0.005)(e) Gaussian Noise(.01) (f) Salt & Pepper Noise(.001) (g) Rotation (45^0) (h) Rotation (135^0) (i) Rotation (225^0) (j) Rotation (315^0) (k) Shear attack(x-1,y=0) (l) Crop attack (100,100)

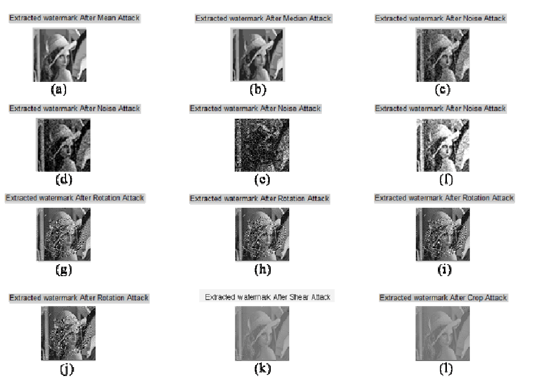

Figure.22. Extracted Patient images from US Watermarked Images with 'db2' after (a) 3×3 window mean attack,(b) median attack,(c)-(f) rotation attacks,(g)-(j) noise attack, and (k) shows shear attacks and (l) crop attacks

The visual quality of watermarked medical images and their extractions are almost similar to that obtained using 'db2' wavelet at level-1. Hence DWT-BAT watermarking algorithm is independent of mother wavelet and level of decomposition of the wavelet. Comparing Noise attacked watermarked images in DWT-BAT with other watermarking algorithms proposed by us for medical image watermarking is shown in figure 25.

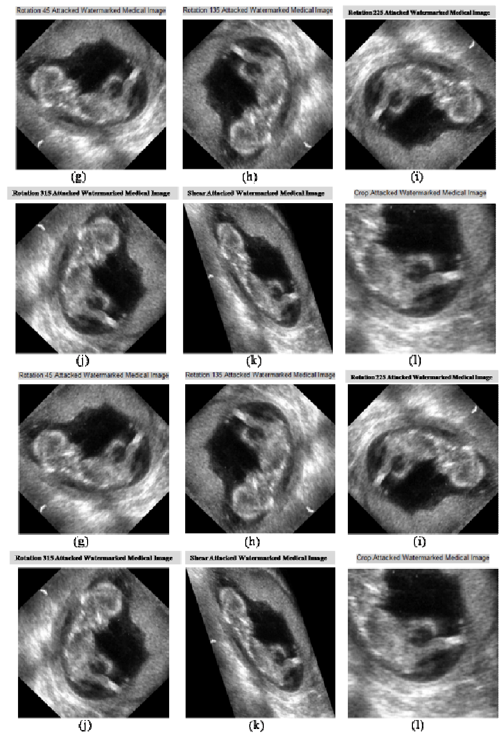

Figure.23. Attacked watermarked CT Images(a)Mean (b) Median (c)Gaussian Noise(.001) (d) Gaussian Noise(0.005)(e) Gaussian Noise(.01) (f) Salt & Pepper Noise(.001) (g) Rotation (45^0) (h) Rotation (135^0) (i) Rotation (225^0) (j) Rotation (315^0) (k) Shear attack(x-1,y=0) (l) Crop attack (100,100)

Figure.24. Extracted Patient images from US Watermarked Images with 'db2' after (a) 3×3 window mean attack,(b) median attack,(c)-(f) rotation attacks,(g)-(j) noise attack, and (k) shows shear attacks and (l) crop attacks

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From figure 25 it is clear that DWT-BAT has produced exceptionally good watermarked medical images than the remaining wavelet based medical image watermarking algorithms.

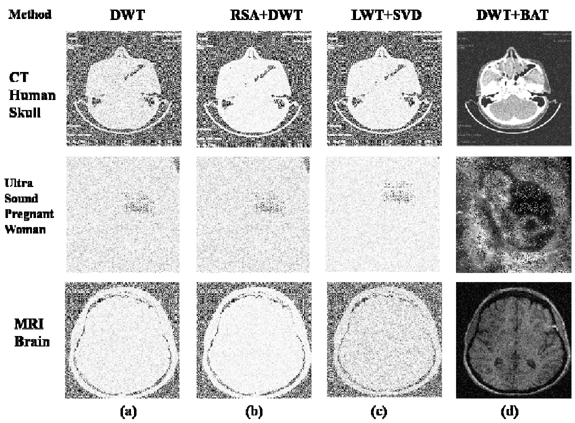

Figure.25. *Noise attacked watermarked medical images using (a) DWT based (b) RSA-DWT based (c) LWT-SVD based and (d) DWT-BAT based algorithms*

6. CONCLUSION

A DWT-BAT medical image watermarking algorithm was proposed in this research paper. Three different types of medical images such as MRI, CT and US are used as cover images and a patient image is used as watermark to load the medical image. Medical image is loaded with patient image in wavelet transform domain. The amount of load from watermark is optimized by using BAT algorithm. This process of watermarking helps in retaining the quality of the medical image. Testing of the proposed DWT-BAT watermarking procedure is accomplished by simulating various possible attacks on watermarked images when transported through internet. The objective of choosing an optimum psnr for watermarking is accomplished by applying BAT algorithm. Experimental results show that the DWT-BAT algorithm demonstrates superior protection on unsecured networks compared to normal DWT based watermarking algorithms proposed earlier. The experimental results prove this fact visually and mathematically in this paper. The proposed method does not put constraints on the resolution of the watermarks used. The DWT-BAT watermarking algorithm is also independent of mother wavelet and wavelet decomposition level.

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