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AN APPROACH FOR TAMPER DETECTION AND RECOVERY OF MEDICAL IMAGES PRESERVING ROI

[1]Jaee P. Gaikwad, [2]Dr. Mrs. K. V. Kulhalli
[1]Student, [2]Dean DYPCET Kolhapur
Electronics and Telecommunication Engineering
D.Y.Patil College of Engineering. & Technology, Kasaba Bawada, Kolhapur, India

Abstract: Now a days, in every field we use internet for variety of applications. One of the use of internet is in medical field where there is an exchange of medical information over the internet between different hospitals, research centers for diagnosis purpose. The problem while exchanging medical information is the possibility of tampering, changing medical information of patient. One remedy for this is to use digital watermarking technique which ensures privacy, authenticity & integrity of medical information. In this article, SVD is used as a watermarking technique. Dual watermarks are concatenated, sparse coded & embedded using SVD. Then different attacks are planned on watermarked image & concatenated dual watermarks are extracted. The tampered watermarked image then recovered to restore medical information of patient. For experimental analysis, PSNR & NC are calculated to ensure robustness & transparency.

Index Terms - SVD, DWT, Sparse coding, PSNR, NC

I.Introduction

The government of India has started Digital India program with a vision to transform India into a digitally empowered society & knowledge economy. The aim of the program is paperless work & to connect rural areas with high speed internet networks. So we cannot imagine our future without internet.

The use of internet is increasing in medical fields. Thus medical image watermarking is the need today. There are various methods of watermarking but Singular Value Decomposition is the most suitable method particularly in medical domain. In this paper, SVD is used as a watermarking method. The host medical image is divided into ROI & RONI. The watermark image is formed by concatenating ROI & EPR (Electronic Patient Record).The watermark is embedded in RONI part of host image.ROI is important part in medical image used for diagnosis. Hence it must be protected from malicious attacks over the internet. Hence it is embedded as a watermark.EPR is also important which is used to authenticate the patient identity. In case of attacks while transmission between hospitals, ROI & EPR are protected against attacks due to the robustness of SVD watermarking algorithm & sparse coding of watermark.

II.Terminology & Features of Watermarking

The following are the terms used in watermarking process.
Host Image: It is the original image of user in which watermark is added.
Watermark Image: It is the image of user information which is to be added in host image.
Embedding Process: It is the process of adding watermark into host image.
Extraction Process: It is the process of subtracting watermark from host image. It is the opposite process of embedding.
Watermarked Image: The host image with embedded watermark image is called watermarked image.
The features of watermarking are as follows:
Security: Security is provided using watermarking because watermark is embedded inside host image.
Privacy: As watermark is invisible, privacy is maintained.
Integrity: The contents of watermark can not be changed as it is embedded inside the host image.
Imperceptibility: By adding watermark, the watermarked image looks similar to original host image. No one can notice the added watermark.
Robustness: Even though watermarked image undergoes attacks, watermark is safely extracted without degradation.

III.Different domains of Watermarking

Digital image watermarking can be done in both spatial domain and transform domain. In spatial domain the watermark bits directly added to the pixels of the cover image. Spatial domain methods can be easily modelled and analysed mathematically. However, the embedded watermark can be easily destroyed or removed by signal processing attacks such as filtering.

The robustness and imperceptibility of the watermarked images can be improved by performing watermarking in frequency domain. Frequency domain techniques can provide better robustness against compression and filtering attacks, because the watermark coefficients spread throughout the cover image. The watermarking techniques in frequency domain are DFT ,DCT ,DWT ,SVD ,hybrid DWT-SVD.

In this paper, DWT and SVD methods are discussed.

IV.Different Watermarking Methods

A. Discrete Wavelet Transform (DWT):

Discrete Wavelet Transform is a transform that is used in numerical as well as functional analysis. In this transform, the wavelets are sampled with the discrete values. The main advantage of this transform over Fourier Transform is that it captures both frequency and location information. The DWT technique decomposes the original image into four sub bands LL, LH, HL and HH.

Embedding Process:

1. First host image is taken & converted into gray image.
2. Then RONI part of host image is taken.
3. DWT is applied on RONI image such that it is decomposed into four sub-bands.
4. Then watermark image is taken which is to be embedded into RONI part of host image.
5. Watermark image undergoes DWT
6. The watermark is then embedded into the lower frequency sub-band of host image using the scale factor (α)

   i.e. $WI=H+ \alpha(W)$
7. Finally inverse DWT is performed to get watermarked image.

Extraction Process:

1. As done in embedding process, DWT is applied on host, watermark & watermarked image.
2. Then extraction is applied to decomposed watermarked image using same scaling factor (α)

   $$EWI=(WM - O)/ \alpha$$
3. Finally inverse DWT is applied to get extracted watermark image.

B. Singular Value Decomposition (SVD):

SVD decomposes a matrix C into one singular S and two orthogonal matrices - U and V - such that $UTU = I$, $V\,T\,V = I$ and S= diag($\sigma 1$, $\sigma 2$, ...). Here, I represents identity matrix, ($\sigma 1$, $\sigma 2$, ...) are called singular values of C, U are called left singular values of C, and V are called right singular values of C.

$$C = USV\,T$$

Embedding Process:

1. Similar procedure is carried out to get RONI image from host image.
2. SVD is applied on both RONI part of host image & watermark image.
3. Then watermark is embedded into RONI image using scale factor(α).

   $$WI=H + \alpha\ (W)$$
4. SVD is performed on embedded image.
5. Inverse SVD is applied to get watermarked image.

Extraction Process:

1. SVD is performed on watermarked image.

   $$WI=S_w U_w V_w^T$$
2. Then the extraction is applied to the resultant SVD image using the same value of scale factor (α) *i.e.*, $EWI= (WI - S) / \alpha$
3. Inverse SVD is applied on resultant image to get extracted watermark image.

V.The Proposed Method

The proposed method consists of four phases: Watermark generation, Embedding , Extraction and Tampering & Recovery.

A. Watermark generation phase:

1. Host image is taken and it is separated into ROI & RONI image manually.

fig 1: Host Image

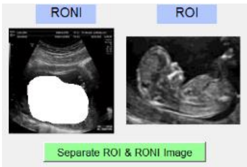


fig 2 : ROI and RONI Images

2. Watermark image (EPR) is taken and ROI & watermark images are concatenated

fig 3 : Watermark Image

fig 4 : Concatenated Watermark Image

Sparse coding is applied on concatenated watermark to get final watermark image which is to be embedded. The essential premise of sparse representation is that a sparse linear combination of basis vectors from a basis set can mimic a natural signal. We presume that multiple classes of samples are present in a hyperspectral image. The training set X is created by integrating all training samples from various s classes because it is initially uncertain to which class the test sample belongs. We construct a matrix $X \in R^{m \times n}$ where *n* denotes training samples and each object has *m* dimensional features, $y \in R^m$ represents a testing sample. Then, the test sample can be approximately represented by multiplying the dictionary *X* with a sparse vector α

$$y = X\alpha$$

where vector α is expected to be sparse. The sparser the recovered α is, the easier it is to accurately determine the class of the test sample y. The sparse vector α can be obtained by solving the following optimization problem.

$$\alpha_1 = \arg\min \|\alpha\|_0 \text{ s.t } y = X\alpha \quad .$$

It is obvious that the solving process of (6) is a NP-hard problem, the computational efficiency is astoundingly low. The minimum l_1-norm solution will approximate the minimum l_0-norm solution based on Restricted Isometry Property (RIP) [19]. Moreover, $y = X\alpha$ cannot hold exactly since test sample may include noise. (6) thus can be rewritten as

$$\alpha_2 = \arg\min \|\alpha\|_1 \text{ s.t } \|y - X\alpha\|_2$$

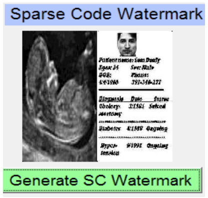
Furthermore, (7) is transformed to the following form,

$$\hat{\alpha} = \arg\min \|\alpha\|_1 + \lambda \|y - X\alpha\|_2$$

where λ is a compromise between data reconstruction error and sparsity, satisfying λ >0. For this optimization problem, there are many methods [20-22] can be used to obtain the solution, which are proper for hyperspectral image data with massive training samples. Equation (7) is used to reconstruct the hyperspectral image, and calculate the redundancy of the *i*-th class as follows [23]:

$$r_i(y) = \left\| y - X_i \hat{\alpha}_i \right\|_2 \text{, i=1,2,...,} s \quad ,$$

and the testing sample y is assigned to the class whose labelled samples provide the smallest representation error.



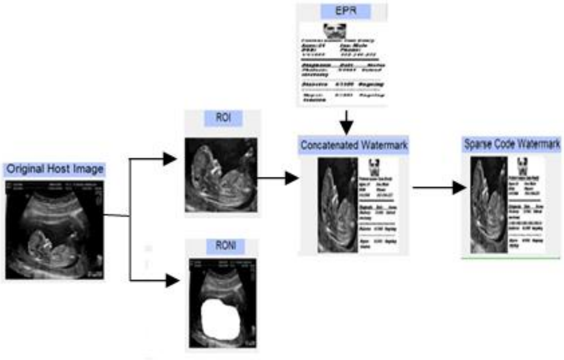


fig 5 : SC Watermark Image fig 6 : Watermark Generation Process

B. Embedding phase:

Here the sparse coded watermark is embedded into the RONI image to get watermarked image.

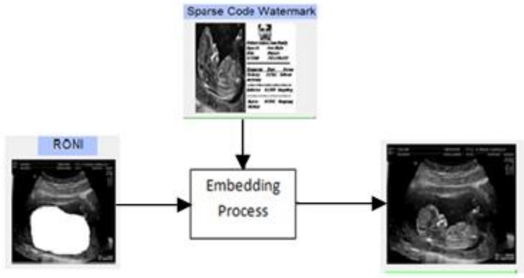


fig 7 : Watermark Embedding Process

C. Extraction & Recovery phase:

a) In this phase, watermarked image undergoes various attacks.

b) Consider, the watermarked image is attacked with salt & pepper noise.

fig 8 : Watermarked image attacked with salt & pepper noise.

c) Then embedded watermark is extracted from this attacked watermarked image.

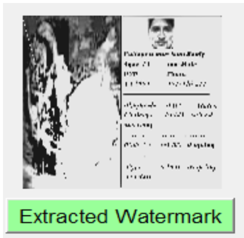


fig 9 : Extracted watermark from attacked image

d) The attacked watermarked image is recovered by replacing ROI .

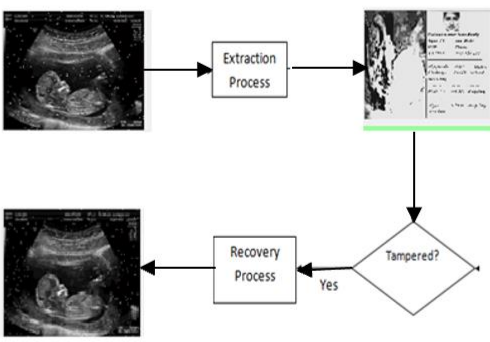


fig 10 : Recovered Watermarked Image fig 11 : Extraction & Recovery Process

VI.Experimental Study & Results:

A. Experimental study:

To evaluate the performance of proposed method, ultrasound medical images of size 512 x 512 are used as host images & 512 x 512 EPR images are used as watermark images as shown in fig (12 and 13). MATLAB is used for simulation.

Table 1: Host Images

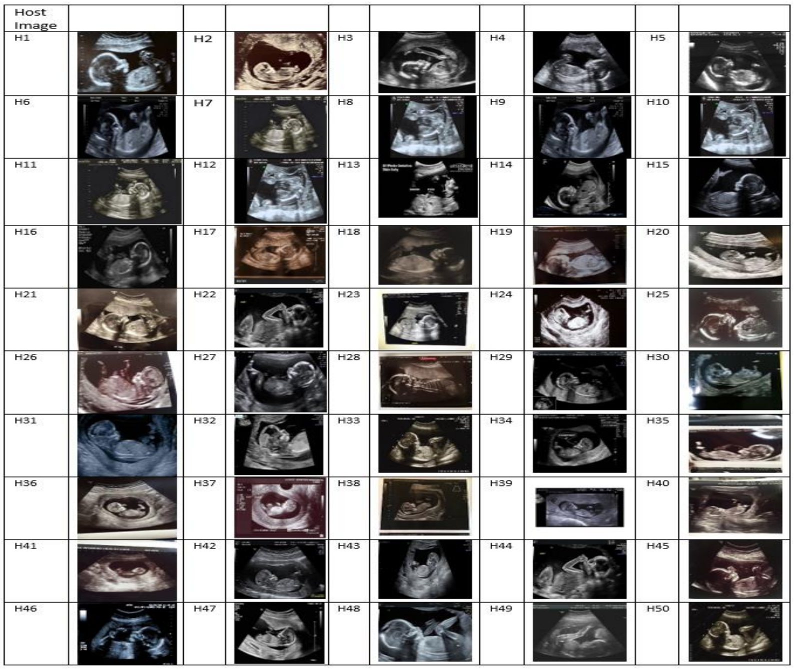


fig 12 : Ultrasound images used as host images

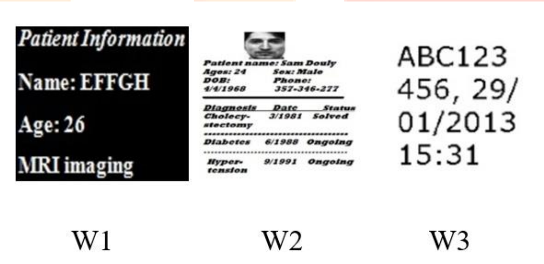


fig 13 : EPR as watermark images

B. Evaluation Parameters:

Watermarking involves changes in the watermarked images as we are embedding some information into it. These changes may reduce the quality of watermarked images. Hence to measure the quality of watermarked image & extracted watermark, PSNR & NC are computed to check imperceptibility & robustness of watermarking. Imperceptibility means how both original & watermarked images are look like the same. PSNR is used to check imperceptibility. Robustness means even your watermarked image undergoes any kind of attack then also watermark is extracted successfully without any degradation. Thus it indicates how your watermarking method is robust to any kind of attacks. NC is used to check robustness. Higher the values of PSNR & NC means better is the imperceptibility & robustness. The parameters can be calculated as,

1. PSNR :

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

Where I = original host image

K= watermarked image

The PSNR in dB is given by,

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

Where MAX=Maximum possible pixel value of the host image which is equal to 255.

2. NC :

$$NC = \frac{\sum_i \sum_j W \times W'}{\sqrt{\sum_i \sum_j W^2 \times \sum_i \sum_j W'^2}}$$

Where W=original watermark

W'=Extracted watermark

C. Quality Assessment

Quality assessment is done by using two subjective & objective methods. In subjective assessment, medical experts check whether there is any loss of medical information after watermarking. Experts visually see both original & watermarked images to confirm the similarity between them. If they are similar then we conclude that there is no any loss of medical information in watermarked image.

In objective assessment, we calculate PSNR & NC values to the check the similarity between two images.

From subjective & objective analysis, we can say that there is no any loss of medical information.

D. Experimental setup:

The experimental setup used for proposed method is shown in figure below with sample images. GUI for Watermark generation , embedding & extraction is shown in fig 14.

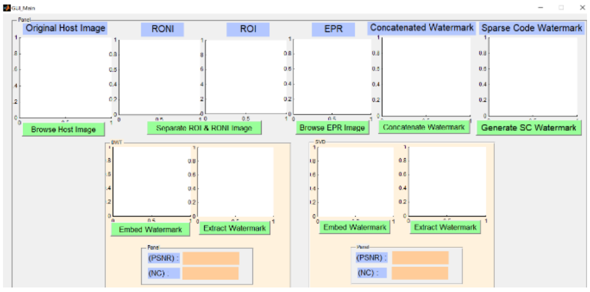


fig 14 : GUI for Watermark generation , embedding & extraction

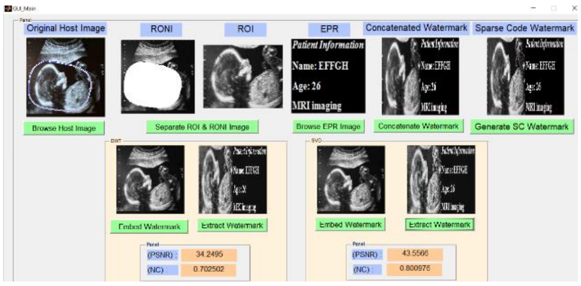


fig 15 : Results for Sample 1

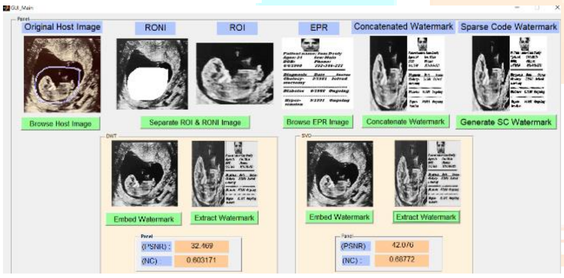


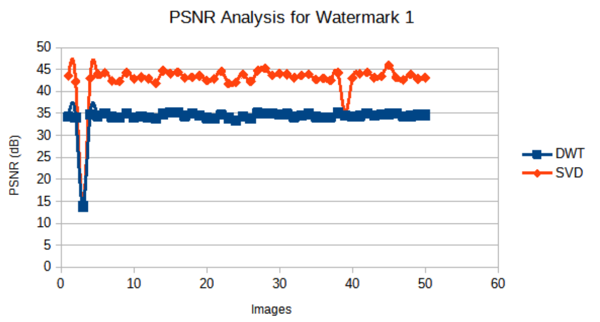
fig 16 : Results for Sample 2

To evaluate the performance of proposed methods, PSNR & NC values are calculated which are shown in Table 1

Table 1 PSNR & NC values

	Watermark 1(W1)				Watermark 2 (W2)				Watermark3 (W3)			
Host Images	DWT		SVD		DWT		SVD		DWT		SVD	
	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC
H1	34.2495	0.7025	43.5566	0.8009	32.5217	0.5747	43.2325	0.6553	32.366	0.5730	43.1867	0.6533
H2	34.0873	0.7552	42.2466	0.8611	32.469	0.6031	42.076	0.6877	32.321	0.5963	42.0512	0.6799
H3	13.8563	0.6900	13.8563	0.7867	13.8563	0.5730	13.8563	0.6533	13.8563	0.5806	13.8563	0.6620
H4	34.814	0.6761	43.0421	0.7708	32.6292	0.5789	40.3805	0.6601	32.4686	0.5890	40.6046	0.6715
H5	34.4023	0.7072	43.9089	0.8064	32.5612	0.5940	43.803	0.6773	32.4045	0.5997	43.756	0.6838
H6	34.9663	0.6554	44.2324	0.7472	32.6929	0.5786	43.5793	0.6598	32.5124	0.5802	43.5261	0.6615
H7	34.1437	0.6988	42.3888	0.7968	32.509	0.5837	42.078	0.6655	32.3595	0.5786	42.0509	0.6597
H8	34.0362	0.6992	42.3084	0.7973	32.453	0.5584	42.1887	0.6367	32.3117	0.5610	42.1938	0.6396
H9	34.9883	0.6735	44.2381	0.7679	32.7013	0.5755	43.599	0.6562	32.5264	0.5838	43.5524	0.6656
H10	34.0757	0.7237	42.8683	0.8251	32.4678	0.5883	42.7218	0.6707	32.3262	0.5846	42.7042	0.6666
H11	34.3612	0.6883	43.2365	0.7848	32.5519	0.5860	43.1643	0.6681	32.3923	0.5897	43.1053	0.6724
H12	34.0405	0.7159	42.9078	0.8162	32.4544	0.5832	42.7692	0.6649	32.3178	0.5914	42.7575	0.6743
H13	33.8666	0.6879	41.9139	0.7843	32.395	0.5599	41.3407	0.6384	32.2594	0.5680	41.3333	0.6476
H14	34.8859	0.6879	44.7007	0.7843	32.6786	0.5814	43.9643	0.663	32.5108	0.5873	43.9019	0.6696
H15	35.2308	0.6664	44.0642	0.7598	32.7512	0.6122	43.6697	0.6980	32.5619	0.6122	43.6334	0.7042
H16	35.2239	0.6422	44.3547	0.7322	32.749	0.5960	43.4192	0.6795	32.5697	0.6061	43.3334	0.6911
H17	34.4581	0.6279	43.1172	0.7159	32.5766	0.5418	43.0986	0.6177	32.4234	0.5529	43.1156	0.6304
H18	34.9776	0.6785	43.2659	0.7736	32.6978	0.6114	42.4038	0.6971	32.5297	0.6339	42.307	0.7228
H19	34.5554	0.6659	43.5763	0.7592	32.6046	0.5471	42.9641	0.6239	32.4483	0.5609	42.9008	0.6395
H20	33.9595	0.6796	42.4969	0.7748	32.4278	0.5803	41.9645	0.6617	32.2833	0.5784	41.9215	0.6595
H21	33.8898	0.6822	42.8499	0.7779	32.3984	0.5604	42.5013	0.6390	32.2554	0.5571	42.4193	0.6352
H22	34.704	0.6853	44.5493	0.7814	32.628	0.5629	44.4007	0.6418	32.4698	0.5787	44.4099	0.6598
H23	33.9411	0.6609	41.7553	0.7536	32.4112	0.5677	41.4039	0.6473	32.2582	0.5581	41.3796	0.6364

H24	33.41	0.6929	42.0546	0.7901	32.2302	0.5430	42.0178	0.6191	32.1115	0.5384	42.0353	0.6139
H25	34.3246	0.7009	43.8992	0.7991	32.5439	0.6081	43.5623	0.6934	32.3851	0.6002	43.5109	0.6843
H26	33.8828	0.6919	42.2596	0.7889	32.4042	0.5707	42.0683	0.6507	32.2781	0.5962	42.0457	0.6798
H27	35.0651	0.6877	44.7447	0.7841	32.7159	0.5943	44.724	0.6777	32.5698	0.6279	44.7784	0.7160
H28	34.9337	0.6661	45.233	0.7595	32.6924	0.6108	44.9606	0.6964	32.5222	0.6170	44.9285	0.7035
H29	34.9505	0.7006	43.6171	0.7988	32.6969	0.5926	42.9111	0.6757	32.5302	0.5980	42.6833	0.6818
H30	34.7607	0.6744	44.0471	0.7689	32.6582	0.5755	43.7229	0.6561	32.4911	0.5764	43.6686	0.6572
H31	34.8822	0.6380	43.9232	0.7274	32.6792	0.5625	42.7436	0.6400	32.5224	0.5886	43.2392	0.6711
H32	34.1842	0.7046	43.1314	0.8034	32.5018	0.5596	42.8292	0.6380	32.3448	0.5619	42.7845	0.6407
H33	34.5784	0.6890	43.6311	0.7856	32.6162	0.5858	43.4761	0.6679	32.4507	0.5972	43.4519	0.6809
H34	34.8833	0.7156	43.8893	0.8159	32.6872	0.5973	43.3927	0.6810	32.5231	0.6013	43.3374	0.6856
H35	34.229	0.7590	42.709	0.8654	32.5118	0.6052	42.3305	0.6901	32.364	0.5991	42.2964	0.6831
H36	34.1269	0.7062	42.985	0.8052	32.4838	0.5653	42.5603	0.6445	32.3401	0.5768	42.5007	0.6576
H37	34.132	0.6863	42.5099	0.7825	32.4796	0.5960	42.3022	0.6796	32.3419	0.6147	42.2886	0.7009
H38	35.0955	0.6767	44.2288	0.7715	32.729	0.6052	43.9358	0.6900	32.5568	0.6077	43.9189	0.6929
H39	34.5506	0.6283	35.0758	0.7163	32.605	0.5725	33.0524	0.6528	32.4533	0.6015	32.9167	0.6858
H40	34.2662	0.7310	43.0432	0.8335	32.5202	0.5900	42.6965	0.6727	32.372	0.5935	42.6738	0.6767
H41	34.4231	0.7269	44.0054	0.8288	32.5758	0.6181	43.6738	0.7047	32.4165	0.6158	43.6551	0.7022
H42	35.0436	0.6097	44.3321	0.6951	32.7148	0.5816	43.7996	0.6631	32.503	0.5689	43.7294	0.6487
H43	34.4827	0.6456	43.1308	0.7361	32.5792	0.5595	43.0493	0.6379	32.4274	0.5664	43.0344	0.6459
H44	34.7442	0.6676	43.4583	0.7612	32.6492	0.5629	43.3662	0.6418	32.4794	0.5715	43.3464	0.6516
H45	34.8708	0.7147	45.9629	0.8148	32.6777	0.6289	45.1269	0.7171	32.5085	0.6312	45.0619	0.7197
H46	34.9729	0.6804	43.1513	0.7758	32.7024	0.5955	43.0598	0.6789	32.5322	0.6030	43.0788	0.6875
H47	34.3604	0.7025	42.6431	0.8010	32.5425	0.5796	42.2933	0.6608	32.3991	0.6019	42.238	0.6862
H48	34.4255	0.6874	43.8495	0.7838	32.5734	0.5656	43.6997	0.6449	32.4166	0.5738	43.7015	0.6542
H49	34.6022	0.6787	42.826	0.7738	32.6181	0.6021	42.6054	0.6865	32.433	0.5876	42.5617	0.6700
H50	34.6636	0.6807	43.1324	0.7761	32.6321	0.5917	43.0609	0.6747	32.4644	0.5954	42.966	0.6789



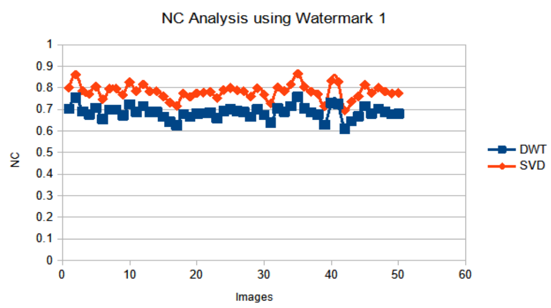


fig 17 : PSNR analysis of 50 Images for Watermark 1 fig 18 : NC Analysis of 50 images for Watermark 1

E. Robustness Results & Analysis:

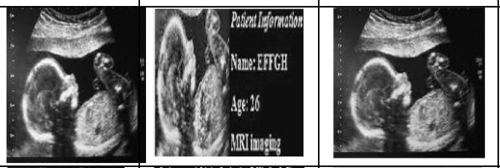
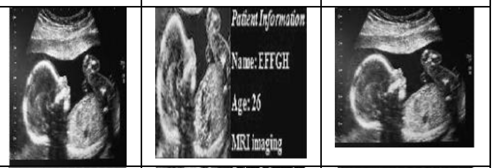
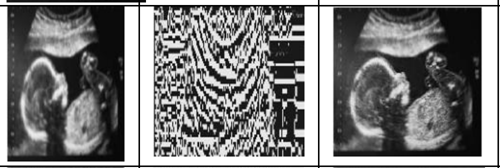
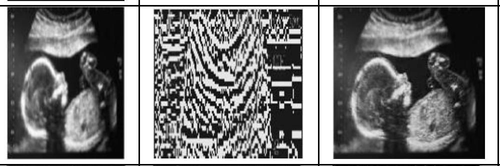
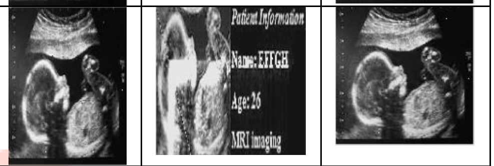
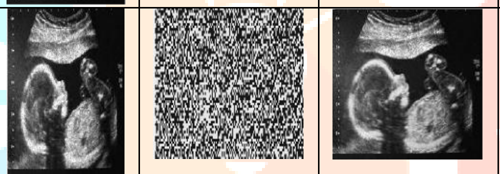
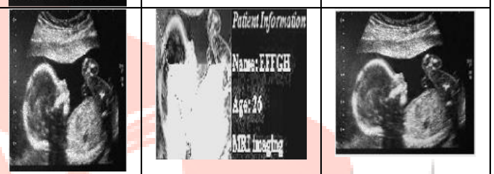
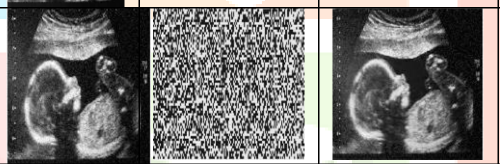
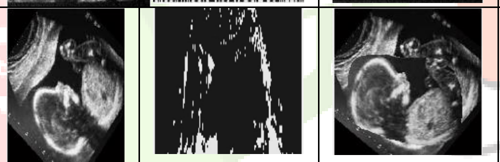
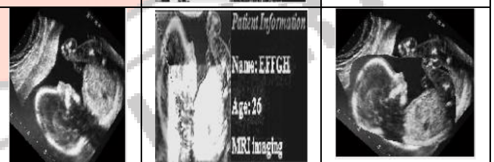
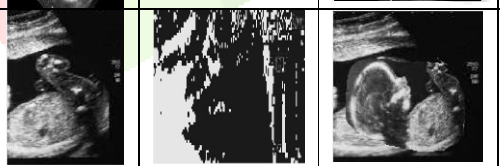
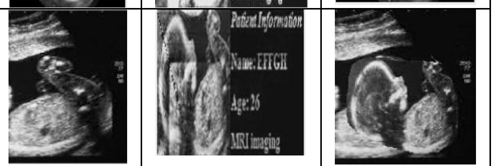
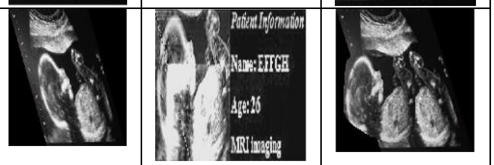
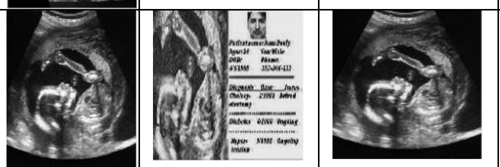
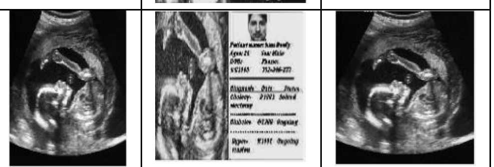
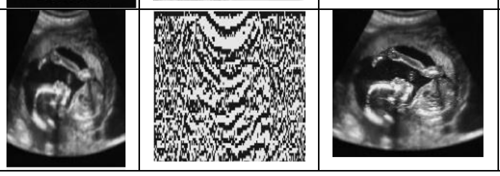
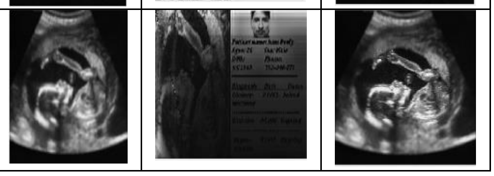
To check the robustness of proposed methods, different kinds of attacks are performed on watermarked images.
To perform attacks the following GUI is used. Here first select type of attack then click on attacked image button to display attacked image. Then click on extracted watermark button which displays watermark image extracted from attacked watermarked image. PSNR & NC values are also displayed in Table 2.

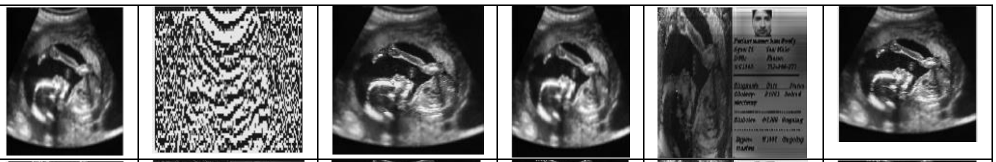
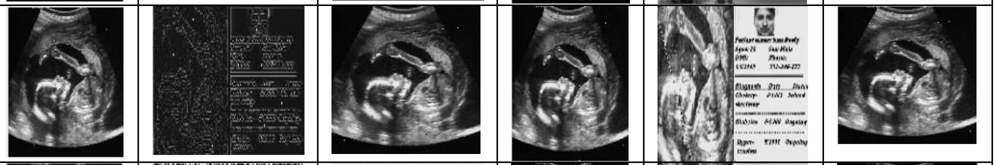
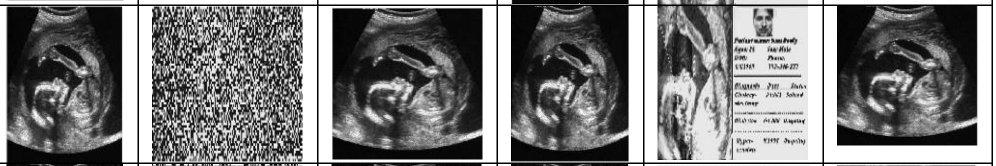
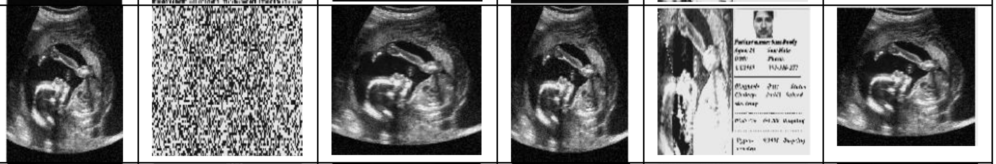
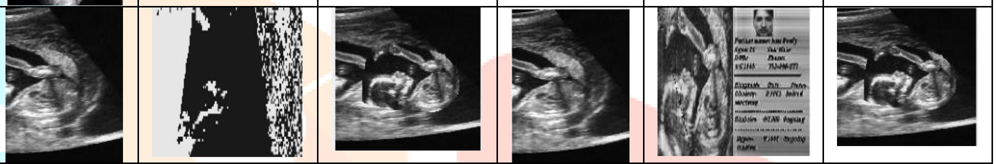
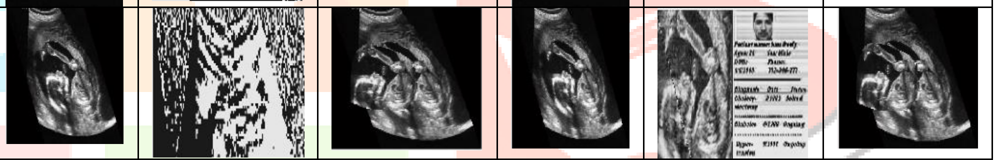
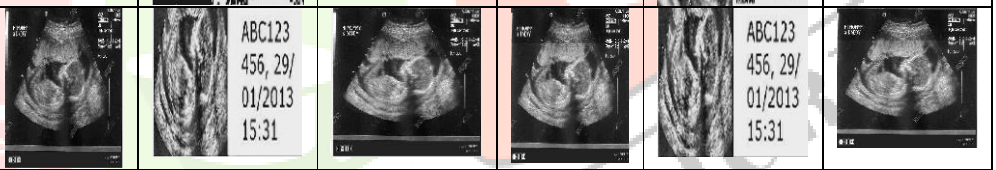
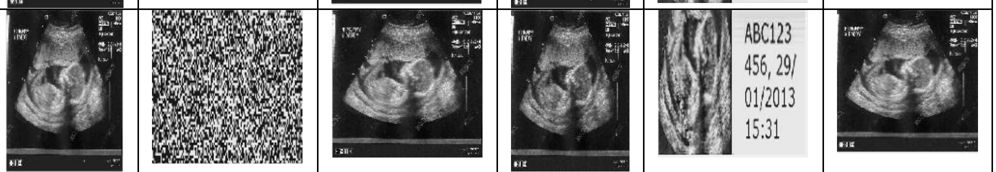
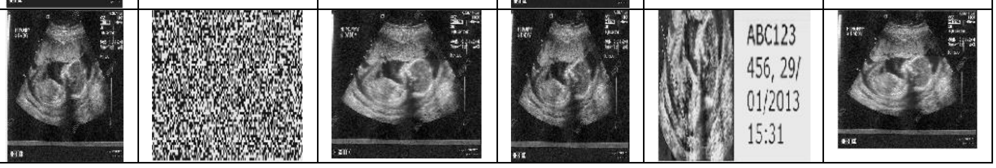
fig 19 : GUI for applying attacks on Watermarked Images fig 20 : Crop attack on Watermarked Image

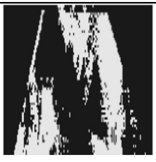
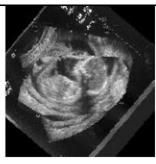
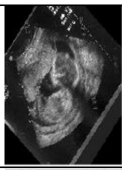
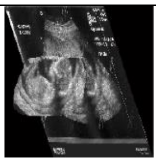
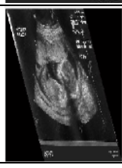
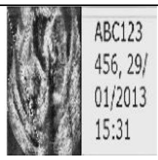
Table 2 PSNR & NC values for different types of attacks

Image	**Type of Attack**	**DWT**		**SVD**	
		PSNR	NC	PSNR	NC
H1 + W1	No Attack	34.2667	0.6969	43.5002	0.7946
	Mean	9.0726	0.0418	9.0726	0.4115
	Blurring	9.0720	0.0531	9.0726	0.7216
	Salt & Pepper noise	12.5988	0.3550	12.3953	0.7095
	Speckle noise	9.4287	0.0215	9.4222	0.5862
	Gaussian noise	9.0747	-0.0180	9.0760	0.6085
	Rotation	3.3904	0.0698	3.3904	0.6329
	Crop	3.2164	0.0659	3.2164	0.7571
	Shearing	3.7327	-0.0773	3.7327	0.7159
H3 + W2	No Attack	32.5615	0.5749	43.196	0.6554
	Mean	8.7171	0.0061	8.7171	0.2031
	Blurring	8.7165	0.0038	8.7165	0.4368
	Salt & Pepper noise	12.4462	0.0150	12.5394	0.6209
	Speckle noise	9.8785	-0.0009	9.8771	0.5579
	Gaussian noise	9.1540	-0.0023	9.1419	0.4996
	Rotation	3.5614	0.0534	3.5614	0.5243
	Crop	3.8808	-0.1414	3.8808	0.4934
	Shearing	4.1393	0.1599	4.1393	0.6384
H17 + W3	No Attack	32.4245	0.5655	43.1987	0.6448
	Mean	6.8860	0.0100	6.8860	0.1914
	Blurring	6.8857	0.0115	6.8857	0.2464
	Salt & Pepper noise	12.5006	-0.1292	12.4014	0.6428
	Speckle noise	10.0801	0.0080	10.0936	0.6346
	Gaussian noise	9.0276	0.0144	9.0357	0.6265
	Rotation	3.9497	0.0330	3.9497	0.5777
	Crop	4.1475	0.0122	4.1475	0.5013
	Shearing	4.2546	0.0907	4.2546	0.6326

Table 3 Attacked images with extracted watermark & recovered image

Image	Type of Attack	DWT			SVD		
		Attacked Image	Extracted Watermark	Recovered Image	Attacked Image	Extracted Watermark	Recovered Image
H1+W1	No Attack						
	Mean						
	Blurring						
	Salt & Pepper noise						
	Speckle noise						
	Gaussian noise						
	Rotation						
	Crop						
	Shearing						
H3+W2	No Attack						
	Mean						

	Blurring	
	Salt & Pepper noise	
	Speckle noise	
	Gaussian noise	
	Rotation	
	Crop	
	Shearing	
H17 +W3	**No Attack**	
	Mean	
	Blurring	
	Salt & Pepper noise	
	Speckle noise	
	Gaussian noise	

	Rotation						
	Crop						
	Shearing						

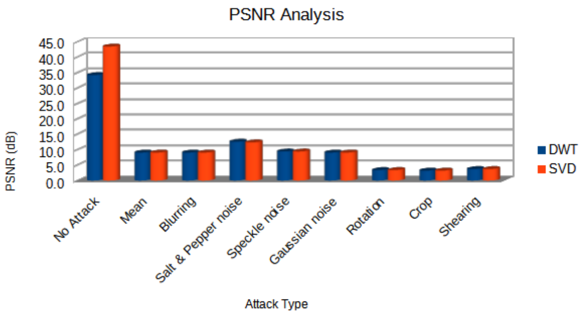


fig 21 : PSNR analysis on Image 1 with attacks and W1

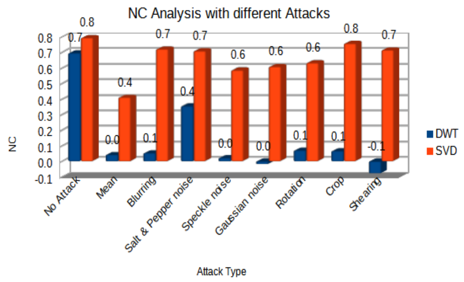


fig 22 : NC Analysis on Image 1 with Attacks and W1

VII.Conclusion

The proposed method can be used for multiple purposes; EPR hiding, authentication of the ROI, and recovering a tampered region. To evaluate the performance of proposed work, quality of the medical images can be assessed by computing Peak Signal to Noise Ratio (PSNR) & Normalized Correlation (NC). The proposed technique not only offer a good tamper correction rate but also a high robustness and perceptual quality of the watermarked image.

VIII.References

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