A Secure Transmission of Medical Images by Single Label SWT and SVD based Non-Blind Watermarking Technique

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Abstract. Healthcare plays a most important part in human life today. Due to high quality of health-care, several dangerous diseases became curable now. But a major concerned problem with high quality healthcare is that it is not equally accessible throughout the world. The part of the problem is that the recipient and also the provider must be physically present within the same place. To overcome this problem information and communication technology has been used as a way by which healthcare can be delivered throughout the world. With the help of internet, medical professionals can be share medical reports and taking advice of experts before diagnosed that person. But use of internet also creates some issues such as security and safety of the medical data and protects their confidentiality, integrity and authenticity. Digital watermarking can be used as an important tool for the security and copyright protection of medical images. A new scheme for non-blind image watermarking is offered in this article that is robust against affine transformation and ordinary image manipulation. The suggested watermarking scheme based on Singular Value Decomposition(SVD) and Stationary Wavelet Transform(SWT). Once SWT is applied to both watermark and cover images, SVD is applied to the lower frequency LL subbands of both images. Now alter singular matrix (a diagonal matrix which contains singular values of image as its diagonal elements) of the cover image using singular matrix of the visual watermark. The proposed technique is robust against nearly all common attacks. Study and experimental results illustrate higher performance of the proposed method in comparison with the DWT method.

Keywords: Digital Image Watermarking, Discrete Wavelet Transform, Stationary Wavelet Transform, Singular Value Decomposition.

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1 Introduction

Modern healthcare infrastructure now becomes very flexible due to the advanced information and communication technology. Medical professionals are now able to consult with each other before diagnosed their patient. Various top medical research institutes of India such as AIIMS and TATA Memorial provide e-diagnosis and several other facilities to the patients whom cannot be able to present at hospital physically. Beside these benefits there are some issues created due to the use of information and communication system in healthcare infrastructure.

In medical information system, medical information such as medical images (diagnosis report) and patient information is transmitted over an unsecured open environment (mostly on internet). This results in the following issues to concerned [1].

- Authentication: A proof that information belongs to correct patient and is issued from the right source.
- Integrity: Information has not been modified by un-authorized users.
- Confidentiality: Only entitled users have access to the information.

These issues rises due to the highly availability of the image manipulation tools for everyone. So it became easy to manipulate the medical information (images) by using these tools. This alteration in medical information may causes of serious mistake in treatment or may be used by any one for illegal purpose such as, fake health insurance claim etc [2].

To resolve these issues, watermarking used to ensure the authenticity and integrity of the medical images during the transmission [3]. But in the case of medical image watermarking, after the embedding of watermark any kind of degradation cannot be allowed [4]. Medical informations are highly sensitive, for example in the MRI or CT scan image any deviation (spot etc) in small part may be seems as a serious injury in brain. Hence the medical image must be kept unchanged (without any loss of information) after watermarking. Thus the selected watermarking method does not introduce any visible affect on the medical images [5].

Watermarking can be explained as the process of hiding data in to a multimedia contain for ensuring the security and authentication. Data for hiding will be any information or another multimedia element. In medical image watermarking, patient information or trademark is embedded in the medical images. Every watermarking algorithm consists of two phases:

a) Embedding Phase: In this phase, we insert the watermark in to the host image. We have to assure that the host image remain unchanged.

b) Extraction Phase: In this phase, we have to extract the watermark and check the watermark to conform the integrity and authentication of received image.

There are two domains for watermarking spatial and transform domain. The spatial domain watermarking is concentrated on region of interest (ROI) and non region of interest (NROI). One should insert the watermark in to the NROI region. Spatial domain watermarking is simple but it is not robust against various attacks [6]. Therefore transform domain watermarking is most favorable for the researchers. Most common watermarking technique in transform domain is to alter the coefficients of singular matrix obtained from singular value decomposition (SVD) of the host (cover) image. The watermarking algorithm based on SVD was first represented by Liu et al. [7]. In their work, the authors apply SVD to the cover image and modify these SVD coefficients by adding the watermark. For finding the modified singular values, they apply SVD transform again on the resultant matrix. After that a known component were combined with these singular values to get the watermarked image. Chandra et al. shows that singular values of the watermark embedded in the singular values of entire cover image [8]. The drawback of SVD-based algorithms is that the degradation of quality of the watermarked image. In addition, SVD based algorithms for the extraction of watermark, are not robust to the common attacks. Sverdlov et al. present a hybrid watermarking scheme based on DCT and SVD and show that embedding data in lowest frequencies is resilient to one set of attacks while embedding data in highest frequencies is resilient to another set of attacks [9].

Li et al. propose a hybrid DWT-SVD technique [10]. The author shows that, after the decomposition of the host image into four sub-bands, SVD is applied to each sub-band and singular values of the watermark embedded into the these sub-bands. Liang and Qi et al. used DWT with SVD technique to cover watermark's singular values in high frequency band (HH) of the host image [11]. Hybrid DWT-SVD watermarking algorithm outmatch the usual DWT algorithm with respect to robustness against Gaussian noise, cropping attacks and compression [12]. Although good performance of DWT methods in Watermarking,but they also suffer from drawbacks. To overcome the drawbacks of DWT based algorithms, there is one solution is to use of Stationary Wavelet Transform (SWT) in place of DWT.

2 TRANSFORMS

2.1 Stationary Wavelet Transform (SWT):

DWT is one of the commonly used method for watermarking, but due to the down-sampling of its bands in DWT method, it does not provide the shift invariance. This causes a major alteration in the wavelet coefficients of the image even for slight shifts in the input image. The DWT shift variance causes erroneous removal of the watermark image [13], seeing as in watermarking, we have to know what is the exact locations of the embedded watermark information. Researchers have proposed different watermarking methods using Stationary Wavelet Transform to overcome this problem.

The SWT is a wavelet transform algorithm designed to overcome the lack of translation-invariance of the DWT. Eq.1 and Eq.2 illustrated analysis and synthesis phase of SWT respectively. Where the input and reconstructed signals are ***f[m]*** and ***f'[m]***. The low pass and high pass analysis filters are ***h[-k]*** and ***g[-k]*** and the corresponding low pass and high pass synthesis filters are ***h[k]*** and ***g[k]***. At level ***j***, ***cj*** and ***dj*** are the low-band and high-band output coefficients. SWT analysis and synthesis are given as follows [9]:

a) Analysis:

$$c_j[k] = (c_{(j+1)}[k] * h_j[-k])$$
$$d_j[k] = (c_{(j+1)}[k] * g_j[-k]) \tag{1}$$

b) Synthesis:

$$c_{(j+1)}[k] = \frac{1}{2}(c_j[k] * h_j[k] + d_j[k] * g_j[k]) \tag{2}$$

Here * denotes convolution. SWT eliminates down sampling and up sampling of coefficients during each filter-bank iteration. The block diagram shown in figure 1 depicts the digital implementation of SWT [23][24].

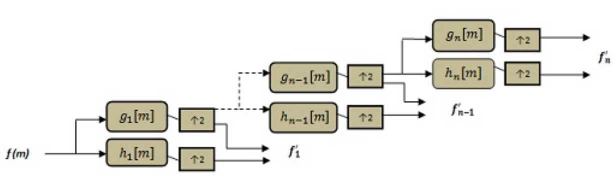


Figure 1: A *n* level SWT filter bank

In the above diagram, filters in each level are up sampled versions of the previous as shown in Figure 1 [23,24].

In the SWT analysis, stationary representation of the input sequence is obtained by eliminating down sampling. Since frame expansion increases robustness with respect to additive noise, SWT based signal processing method is more robust than DWT method.

2.2 Singular Value Decomposition (SVD):

Singular Value Decomposition transform is a linear algebra transform which is used for decomposition of a real or complex matrix with numerous applications in various fields of image processing [15]. As a digital image can be represented in a matrix form with its entries giving the intensity value of each pixel in the image, SVD of an image M with dimensions m x m is given by:

$$M = USV^T$$

Where, U and V are orthogonal matrices and S known as singular matrix is a diagonal matrix carrying non-negative singular values of matrix M. The columns of V and U are called right and left singular vectors of M, in that order. They mainly specify the geometry details of the real image. Left singular matrix i.e. U represents the horizontal details and right singular matrix i.e. V represents the vertical details of the real image. The diagonal values of matrix S are set in decreasing order which signifies that importance of the entries is decreasing from first singular value for the last one, this feature is employed in SVD based watermarking techniques. There are two main properties of SVD to employ in digital watermarking techniques [16]:

- Small variations in singular values does not affect the quality of image and,
- Singular values of an image have high stability so; they do not change after various attacks.

3 PROPOSED METHOD: SWT-SVD BASED WATERMAKING

3.1 Watermark embedding:

In embedding phase of proposed work, we have two images. First one is host image and second one is watermark image. The steps of watermark embedding algorithm are as follows:

a) Apply SWT to the cover image to decompose it into LL, HL, LH, and HH subbands.

b) Apply SVD to the low frequency subband LL of the cover image:

$$I^1 = U^1 S^1 V^{1T}$$

c) Apply SWT to the visual watermark.

d) Apply SVD to the low frequency subband of watermark:

$$W = U^W S^W V^{WT}$$

e) Modify the singular values of the cover image with the singular values of watermark image

$$S^{*1} = S^1 + \alpha S^W$$

Where α is scaling factor, S^1 and S^W are the diagonal matrices of singular value of the cover and watermark images respectively.

f) Apply inverse SVD on the transformed cover image with modified singular values.

$$I^* = U^1 S^{*1} V^{1T}$$

g) Apply inverse SWT using the modified coefficients of the low frequency bands (I^*) to obtain the watermarked image.

Figure 2 shows the proposed watermark embedding algorithm.

3.2 Watermark extraction:

When embedding is completed, the watermarked image I^{*1} is obtained and transmitted. After transmission, receiver extract the watermark from the I^{*1}. The steps of watermark extraction algorithm are as follows:

a) Using SWT, decompose the watermarked image I^* into 4 subbands: HH, HL, LH and LL.

b) Apply SVD to low frequency subband LL:

$$S^{*1} = U^{*1} S^{*1} V^{*1T}$$

c) Extract the singular values from low frequency subband of watermarked and cover image:

$$S^{W'} = (S^{*1} - S^1)$$

Where S^1 contains the singulars of the cover image.

d) Apply inverse SVD to obtain low frequency coefficients of the transformed watermark image.

$$W = U^W S^{W'} V^{WT}$$

e) Apply inverse SWT using the coefficients of the low frequency subband (W) to obtain the watermark image.

Here α is known as Scaling Factor of watermarking approach and its value lies between 0 to 1 depending upon the requirement of watermarking approach. If the value of α tends to 1 then the watermark is partially visual in the watermarked image, but if α tends to 0, visibility of the watermark in watermarked image reduces.

Figure 3 shows the proposed watermark extracting algorithm.

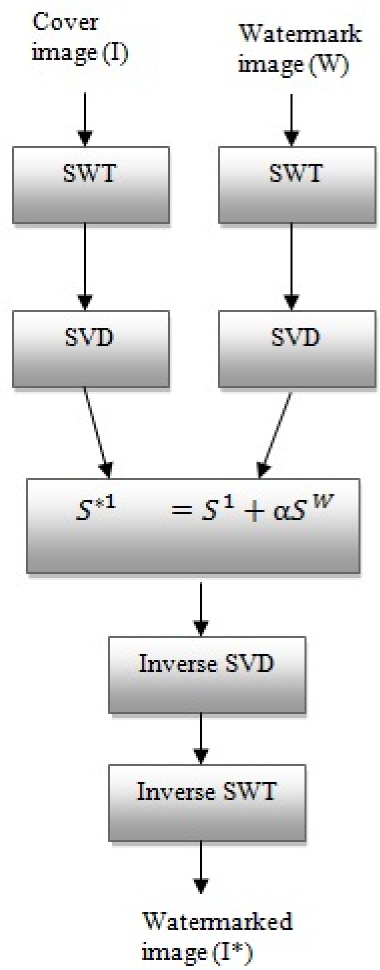


Figure 2: Block Diagram of the proposed watermark embedding algorithm

4 EXPERIMANTAL RESULTS AND DISCUSSION

In this work, a gray scale image of size 512x512 was chosen as our host image, and the watermark image with same size. In our experiment, we used the scaling factor $\alpha = 0.25$.

Figure 4 shows cover image, watermark, watermarked image and the extracted watermark.

The performance of our method can be evaluated on the basis of these two properties.

a) **Property of Imperceptibility**
When watermarks are extracted,similarity or Imperceptibility of the watermark and extracted watermark image can be evaluated by the PSNR (Peak Signal to Noise Ratio) criterion:

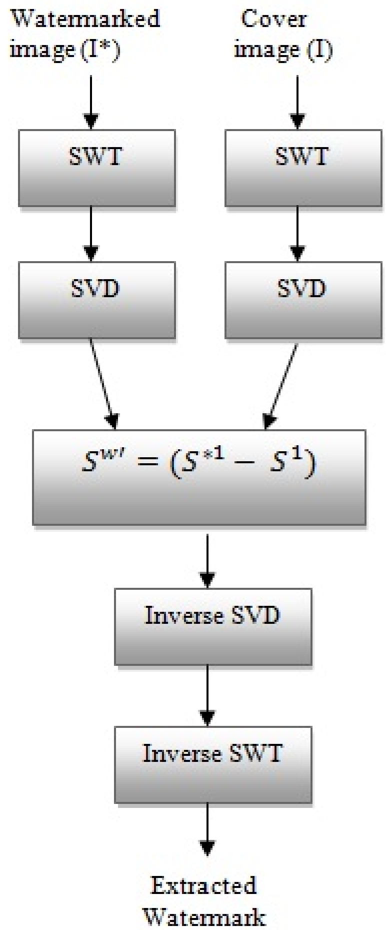


Figure 3: Block Diagram of the proposed watermark extracting algorithm

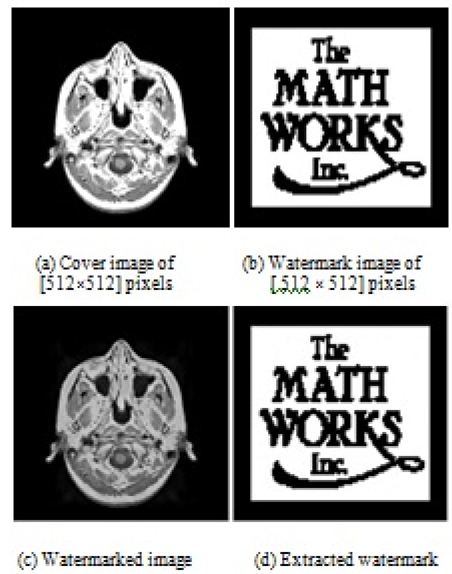


Figure 4: (a) cover image (b) watermark image(c) watermarked image (d) extracted watermark

$$PSNR = 10 \times \log_{10} \frac{[max(X(i,j))]^2}{(MSE)} \text{ (dB)}$$

Where MSE (Mean Square Error) is defined as:

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (H_{i,j} - H'_{i,j})^2$$

Where $H_(i,j)$ and $H'_(i,j)$ are representing the pixel values in the location in the (i,j) of the original host image H and the watermarked image H', respectively.

The result of the extracted watermark image for our proposed method is compared with the original one using the PSNR as metrics. The PSNR of extracted watermark image with our proposed method is 47.7256 db while PSNR by DWT based watermarking method was 41.7726 db. It clearly indicates that the proposed method provides the better results in terms of PSNR values for the extracted watermark image.

b) **Property of Robustness:**
This property ensure that the watermarking method is robust against the various kind of attacks. To evaluate the robustness of our method, we measure the Bit Error Rate(BER) of the watermarked image and watermark after the various attacks.
BER is defined as:

$$BER = \frac{NumberOfErroneousBits}{TotalNumberOfBitsTransmitted}$$

Figure 5 and Figure 6 show the comparison of DWT based watermarking and SWT-SVD based watermarking approaches.

Figure 5 shows a bar graph of values of PSNR and respective MSE for both approaches at scaling factor $\alpha = 0 : 25$. Here approach 1 and approach 2 represent the DWT based watermarking method and our proposed SWT-SVD based watermarking method respectively. The bar graphs clearly show that there is improvement in PSNR with the proposed method as compared to the DWT based watermarking scheme. On the other hand, MSE and BER are reduced for watermark extraction in proposed SWT-SVD watermarking

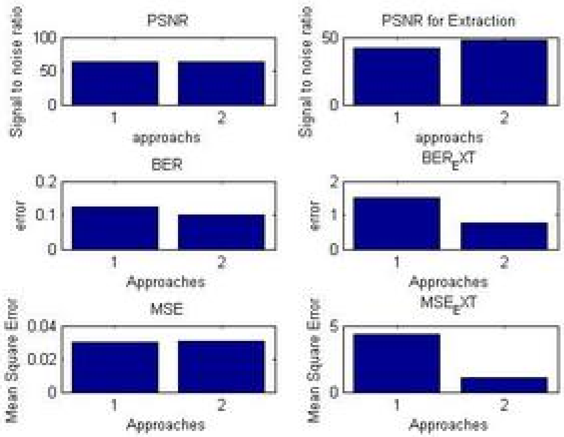
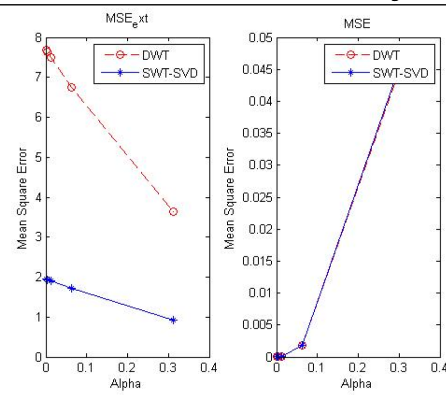
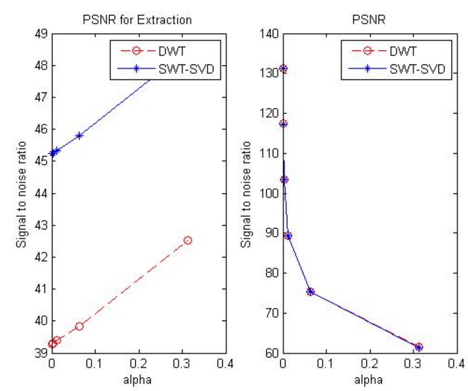


Figure 5: Comparison of DWT and SWT-SVD based approaches at scaling factor $\alpha = 0.25$



(a)MSE



(b)PSNR

Figure 6: Comparison of PSNR and MSE for various values of scaling factor α.

approach (approach 2) as compared to existing DWT based watermarking approach (approach 1).

Figure 6 shows the graph between PSNR and respective MSE for both approaches i. e. proposed approach and existing approach for the various values of scaling factor α. Red line indicates the DWT base approach and Blue line indicates the SWT-SVD based approach. From the figure, it can be seen that in the embedding phase both approaches works equally but in the extraction phase, performance of proposed SWT-SVD approach is better than the DWT. The comparison of both approaches for the different values of α is shown in the table 1.

Figure 7 shows the Bit Error Rate for both approaches with various values of scaling factor α. The performance of SWT-SVD is better than the DWT in both phases, when evaluated in terms of BER. The comparison of both approaches is also shown in the table 1. It can be seen that, if we increase the value of the scaling factor α, values of Bit Error Rate and MSE decreases and the lower value of MSE gives the higher value of PSNR. It can be clearly seen from the results shown in table 1 that the proposed SWT-SVD based approach achieve higher value of PSNR and lower value of BER (for various values of α) as compared to existing DWT based approach.

In our experiment, we also apply various attacks like adding noise (Gaussian, Salt and Pepper, Speckle etc.) and some geographical manipulation (rotate, shifting etc.) on watermarked image and compare the PSNR & BER of extracted watermark to evaluate the robustness of our approach against existing DWT base approach. Figure 8, Figure 9 and Figure 10 shows watermarked images and respective extracted watermarks after the attacks.

Table 2 shows the comparison of both approaches with the application of various attacks on watermarked image for both approaches. we can see that proposed SWT-SVD based approach obtained high PSNR values and low BER values against various attacks as compared to DWT based approach. The result shows that the proposed SWT-SVD based watermarking scheme is more robust for various common attacks as compared to DWT based watermarking scheme.

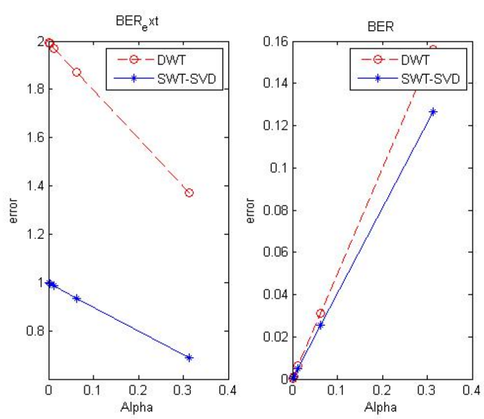
The results in table 2 also shows that after applying the shifting attack over the watermarked image, our proposed SWT-SVD based watermarking approach provide shift invariance capability (PSNR value drop down but is above 35 db), while DWT based watermarking approach provides insignificant value for shift invari-

Table 1: PSNR, MSE and BER for different values of Scaling Factor (α)

	DWT			$SWT-SVD$		
$VariousAttacks$	$MSE-Ext$	$PSNR-Ext(db)$	$BER-EXT$	$MSE-Ext$	$PSNR-Ext(db)$	$BER-EXT$
$\alpha = 0.0001$	7.6844	39.2747	1.9959	1.9475	45.2360	0.9979
$\alpha = 0.0005$	7.6782	39.2782	1.9951	1.9459	45.2395	0.9975
$\alpha = 0.0025$	7.6475	39.2956	1.9911	1.9382	45.2569	0.9955
$\alpha = 0.0125$	7.4950	39.3831	1.9711	1.8996	45.3441	0.9856
$\alpha = 0.0625$	6.7552	39.8344	1.8713	1.7127	45.7941	0.9357
$\alpha = 0.250$	4.3233	41.7726	1.4970	1.0978	47.7256	0.7486
$\alpha = 0.3125$	3.6328	42.5284	1.3723	0.9231	48.4784	0.6862

Table 2: Performance Analysis of Both Approaches

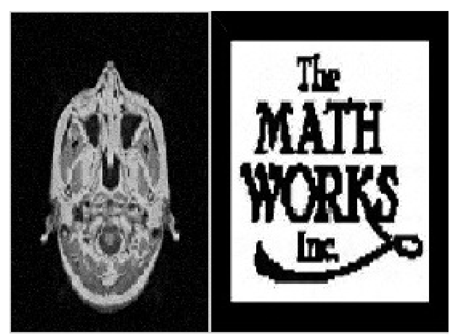
	DWT			$SWT-SVD$		
$Attacks$	$MSE-Ext$	$PSNR-Ext$	$BER-Ext$	$MSE-Ext$	$PSNR-Ext$	$BER-Ext$
Gaussian noise (var 0.001)	18.9051	25.5563	2.7600	7.5461	39.3536	0.0302
Gaussian noise(var 0.005)	27.7315	18.6992	5.6381	13.6876	30.8321	0.1989
Rotate 50 degree	49.3415	3.5445	86.6211	38.3795	8.2312	67.5128
Salt and Pepper (density 0.001)	14.3796	29.7815	0.5605	2.8856	43.5384	0.1285
Salt and Pepper (density 0.005)	20.2022	23.5793	1.0886	11.5801	32.7425	0.4678
Speckle(var 0.04)	21.5414	21.9447	4.8305	11.3122	32.7763	0.6948
Shifting	49.3686	3.5093	14.0286	8.4065	35.7237	0.9918



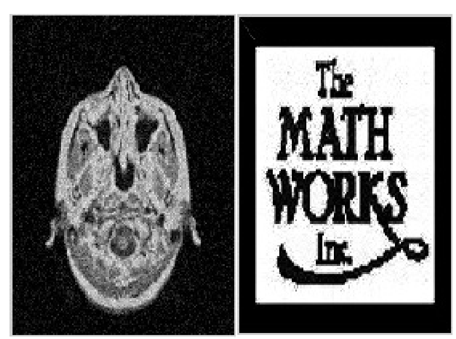
(a)BER

Figure 7: Comparison of BER for various values of scaling factor α

ance (vary poor PSNR value).

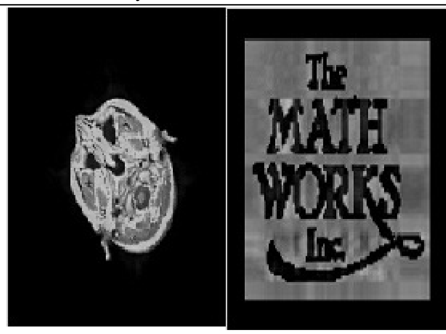


(a)Gaussion [var 0.001]

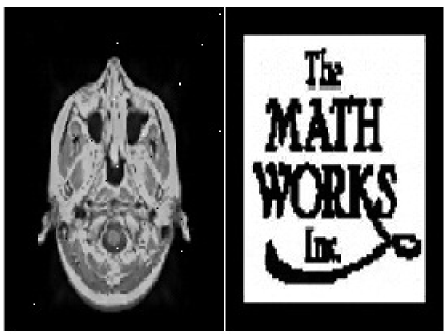


(b)Gaussion [var 0.005]

Figure 8: Part 1: watermarked images and extracted watermark after various attacks



(c)Rotate 50deg



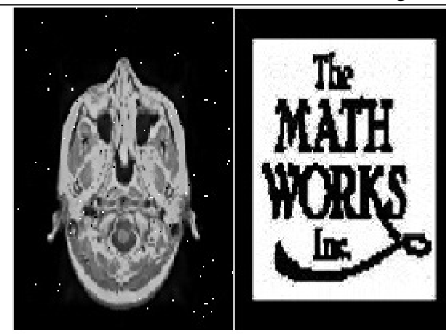
(d)Salt and Pepper [var 0.001]

Figure 9: Part 2:watermarked images and extracted watermark after various attacks

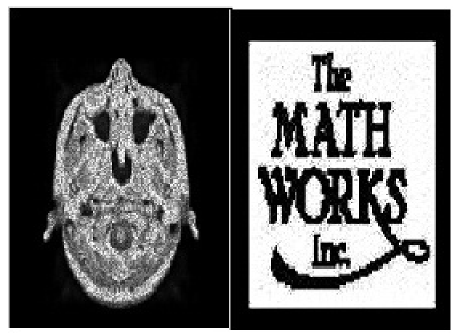
5 CONCLUSION

We have proposed a watermarking method based on SWT-SVD to embed a watermark image, which can be as large as the cover image. Modification in singular values of the host image in SWT domain provides high robustness against common attacks. High value of PSNR and low value of BER for Watermarked image and Extracted Watermark is another beneficial point of the algorithm as a result of SWT implementation. The results demonstrated that the proposed SWT-SVD based watermarking scheme is more robust as compared to DWT based methods. SWT is shift invariant, and its redundancy introduces an over complete frame expansion. It is known that frame expansion enhances robustness with respect to additive noise. Thus, SWT based signal processing tends to be more robust than DWT based techniques. Another advantage of this method is the possibility to embed a large watermark in the cover image.

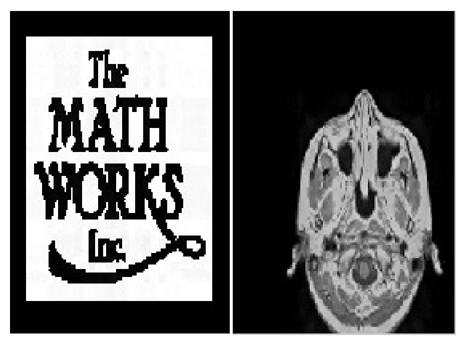
The proposed work presents a robust watermarking algorithm for transmission of images, especially medical images. It also ensures a level of the authentication



(e)Salt and Pepper[var 0.005]



(f)Speckle[var 0.04]



(g)Shifting

Figure 10: Part 3:watermarked images and extracted watermark after various attacks

and integrity of the medical images transmitted. But it is a non-blind watermarking method. The receiver required the original watermark image for extraction of watermark from the watermarked image and confirms the integrity and authentication of the received image. So in future, one can find a blind watermarking method that will not depending on the original images.

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