International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.03, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Signature Based DWT-SVD Watermarking Scheme for Image Security

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ABSTRACT

Security in digital era is very much crucial as the resources held digitally are invisible and untouchable in nature and rather difficult to handle when intruder uses a strong decryption algorithm. A number of security schemes are proposed by both cryptographic and image processing groups for communication of images. Among those, Discrete Wavelet Transform – Singular Value Decomposition based scheme is most important one and is in use quite recently in many applications. In this paper an authentication problem associated with standard DWT-SVD scheme is presented and a solution is proposed in the form of second stage security by generation an additional signature. The unitary matrices are used to generate a signature which is going to be embedded into the fourth level decomposition of cover image. After extracting the watermark at the other end, it will be checked with the signature embedded. If these signatures are matched the unitary matrices will be used to extract watermark from watermarked image.Different attacks are considered and the simulation results have shown that the extraction of watermark after attacks have shown minor effect only.

Keywords:Attacks,Authentication,Signature, SVD, Watermarking

I.INTRODUCTION

Without a doubt, the Internet has revolutionized the way we access information and shareour ideas via tools such as Facebook, twitter, email, forums, blogs and instant messaging.The Internet is also an excellent distribution system for digital media. It is inexpensive,eliminates warehousing and delivery, and is almost instantaneous. Together with theadvances of compression techniques such as JPEG, MP3 and MPEG; the Internet has becomeeven faster, easier and more cost effective to distribute digital media such as audio, video,images and documents over the World Wide Web.In addition to existing web sites and shared networks, the recent development of peer-to-peer(P2P) file distribution tools such as Kazaa, Limewire, Exceem or eMule enables acopious number of web users to easily access and share terabytes of digital media across theglobe. These technologies also significantly reduce the efforts of pirates to illegally record,sell, copy and distribute copyright-protected material without compensating the legalcopyright owners [1][2].

Today, content owners are eagerly seeking technologies that promise to protect their rightsand secure their content from piracy, unauthorized usage and enable the tracking andconviction of media pirates. Cryptography is probably the most common method ofprotecting digital content [3], where the content is encrypted prior todelivery and a decryption key is provided to those who have purchased legitimate copies.However, cryptography cannot help the content providers monitor their goods after thedecryption process; a pirate could easily purchase a legit copy and then re-sell it ordistribute it for free over a shared network.It is therefore important to find a way to protect these digital media with a more stringentmethod, which would enable the vendors and artists / photographers / directors getconfidence in placing and distributing their material over the Internet. Watermarking couldbe such a vehicle [4].Digital watermarking is a field that refers to the process of embedding digital data directlyonto multimedia objects such that it can be detected or extracted later. It has three unique advantages over other techniques such as cryptography.

First of all, it isimperceptible and does not affect the aesthetic of the digital data. Secondly, watermarksbecome fused with the actual bits of the work, unlike headers they do not get removedwhen the work is displayed, copied or during format changes. Lastly, they undergo thesame transformation as the work itself and sometimes the extracted mark can be used tolearn about the history of transformations that the work has undergone [5].

II.SVD

A common problem is that the response matrix is singular or close to singular, so it has no well-defined inverse. Of the various algorithms that have been developed to deal with this problem, singular value decomposition (SVD) has emerged as the most popular. Any matrix can be represented with SVD as follows [6]:

$$M = \sum_{k=1}^{n} \vec{u}_k w_k \vec{v}_k^T$$

where$\mathbf{v}_k$ is a set of orthonormal steering magnet vectors, $\mathbf{u}_k$ is a corresponding set of orthonormal BPM vectors, and $\mathbf{w}_k$ are the singular values of the matrix M. Given the SVD of a matrix, the matrix inverse is: studious

$$M^{-1} = \sum_{k=1}^{n} \vec{v}_k \frac{1}{w_k} \vec{u}_k^T$$

which follows from the orthonormality of the two vector sets. It is immediately apparent from the singular value decomposition if the response matrix is singular one or more of singular values, w_k, are zero. Physically, a zero w_k implies that there is some combination of steering magnet changes, $\mathbf{v}_k$, which gives no measurable change in orbit. The orbit shift from this $\mathbf{v}_k$ is zero at all the BPMs. Removing the terms with zero w_k from the sum in the above equation produces a pseudo inverse for orbit correction which generates no changes in the steering magnet strengths along the corresponding eigenvectors $\mathbf{v}_k$[7-9].

III.DWT

The Fourier analysis is based on decomposing a function per sine waves with different frequencies. Similarly, the wavelet analysis is the decomposition of a function onto shifted and scaled versions of the basic wavelet. A wavelet is a wave shaped function having a limited length with a zero mean value [10-12]. This means that a wavelet decreases fast enough in the frequency domain, and that

$$\hat{\psi}(0) = \int \psi(x)dx = 0 \quad (1)$$

which is a consequence of the condition for the existence of the inverse wavelet transform. Unlike a sine wave, wavelets are generally irregular and asymmetrical.

Fig. 1 Sine function and a wavelet

It is intuitively clear that functions with sharp changes can be analyzed better using short irregular waves than with a smooth infinite sine. The wavelet basis $\{\psi_{j,k}(x)\}_{j,k}$ is generated by the translation and dilatation $\psi(2^{-j} x - k)$of the basic ("mother") wavelet $\psi(x)$. If the basic wavelet $\psi(x)$ ($\psi(x) \equiv \psi_{0,0}(x)$) starts at the moment of x = 0 and ends at the moment of x = N - 1, the shifted wavelet $\psi_{o,k}$starts at the moment of $x = k$ and ends at the moment of $x = k + N - 1$. The scaled wavelet $\psi_{j,0}$starts at the moment of $x = 0$ and ends at the moment of $x = 2^j(N - 1)$. Its graph is scaled (compressed or expanded, depending of the sign of j) by a factor of 2^{-j}, while the graph of the wavelet $\psi_{0,k}$is translated to the right by k, if $k > 0$,

Scaling $\psi_{j,0}(x) = 2^{-j/2}\psi(2^{-j}x)$, (2)

Translation$\psi_{0,k}(x) = \psi(x-k)$. (3)

The basis wavelet is generated by scaling the basic wavelet j times and shifting it by k,

$\psi_{j,k}(x) = 2^{-j/2}\psi(2^{-j} x - k)$ (4)

The multiplier $2^{-j/2}$is a normalizing factor, so that the L_2 norm of the wavelet is equal to one. The space of details on the j-th resolution level Wjcontains functions that are linear combinations of wavelets $\psi_{j,k}(x)$.The 1-D continuous wavelet transform is given by:

$$W_f(a, b) = \int_{-\infty}^{\infty} x(t)\psi_{a,b}(t)dt \quad (5)$$

The inverse 1-D wavelet transform is given by:

x (t) = $\frac{1}{C}\int_{a=0}^{\infty}\int_{b=-\infty}^{\infty} W_f(a,b)\psi_{a,b}(t)db\frac{da}{a^2}$ (6)

where C = $\int_{-\infty}^{\infty}\frac{|\psi\omega)|^2}{\omega}d\omega < \infty$ (7)

$\Psi(\omega)$is the Fourier transform of the mother wavelet ψ (t). *C* is required to be finite, which leads to one of the required properties of a mother wavelet. Since *C* must be finite, then $\Psi(0)=0$ to avoid a singularity in the integral, and thus the $\psi(t)$ must have zero mean. This condition can be stated as $\int_{-\infty}^{\infty}\psi(t)dt=0$ and known as the admissibility condition.

IV.THE STANDARD DWT-SVD WATERMARKING ALGORITHM

In this paper a basic watermarking based on cascading DWT with SVD is proposed. By using DWT the cover image is decomposedinto four frequency bands: LL, HL, LH, and HH bands. LL band characterizeslow frequency, HL and LH characterize middle frequency and HH characterizes high frequency bands,correspondingly. The LL band signifies approximate details, HL band horizontal details, LH vertical details and HH band diagonal details of the image. In this scheme,HH band was selected to embed the watermark image because it comprisesof finer details and contributesimmaterially to the image energy. Thereforeembedding of watermark will not affect the perceptualfidelity of cover image. Furthermore, high energy LL band coefficient cannot be pinchedaway fromcertain point as it will harshly impact perceptual superiority. Also, RavalandRege[13] observedthat watermark image inserted in HH band lasts certain image processing operations or attacks like noiseaddition, intensity manipulation and limitation of the human visual system (HVS) can be exploited byinserting watermark into HH band.

The HVS fails to distinguishvariations made to HH band.Thus the proposed scheme is based on the idea of replacing singular values of the HH band withthe singular values of the watermark. It is observed that singular values lie between 84 and 173 for most of the standard images. If a watermark isselected such that its singular values lies within the given range, then the energy of the singularvalues of watermark image will be roughly equal to the energy of the SVs of the HHband. Thus the replacement of the singular values will not affect perceptual quality of imageas well as the energy content of HH band.Watermark image used for experimentation in this work is preprocessed to have singular valueswithin the range of 0–150 and it closely matches the singular values of the given test images.

a. *Algorithm for watermark embedding:*

i. Watermark 'W' is decomposed using SVD

International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.03, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

$$W = U_w * S_w * V_w^T$$

ii. Apply wavelet (in this work 'haar') and decompose cover image into four subbands: LL, HL, LH, and HH.

iii. Apply SVD to HH band.

$$H = U_H * S_H * V_H^T$$

iv. Substitute the SVs of the HH band with that of the watermark.

v. Apply inverse SVD to obtain the modified HH band.

$$H' = U_H * S_w * V_H^T$$

vi. Apply inverse DWT to produce the watermarked image.

b. Algorithm for watermark extraction:

i. Using the haar wavelet, decompose the (noisy) watermarked image into four subbands: LL, HL,LH, and HH.

ii. Apply SVD to HH band.

$$H = U_H * S_H * V_H^T$$

iii. Extract the SVs from HH band.

iv. Reconstruct the watermark using SVs and orthogonal matrices U_w and $V_w$acquiredusing SVD of original watermark.

$$W_E = U_w * S_H * V_w^T$$

This constitutes a blind decoding as the extraction process don'tneed originalcover image for extracting the watermark image at the receiver.

V.AUTHENTICATION MECHANISM IN THE PROPOSED SCHEME

Zhang and Li [14] observed an authentication problem in the basic SVD based approaches proposedby Zhou and Chen [7], and GanicandAhmetEskicioglu[15]. This section discusses thecommon problem with most of SVD-based schemes in the state-of-art techniques.To make evident the problemassume that two different watermark images were embeddedin an image separately as shown in Figure 2 using the standard SVD system. The watermark images were embedded bychanging the SVs of cover image with the SVs of the watermark images.Decoder guesstimates the watermark by merging SVs extracted from one watermarked imageand using orthogonal matrices of other watermark. Figure 3 shows that the decoder extractedSVs from watermarked image-2 and combine them with orthogonal matrices (U1 and V1*)* forwatermark extraction. As a consequence, watermark-1 is extracted in place of watermark-2.

International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.03, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

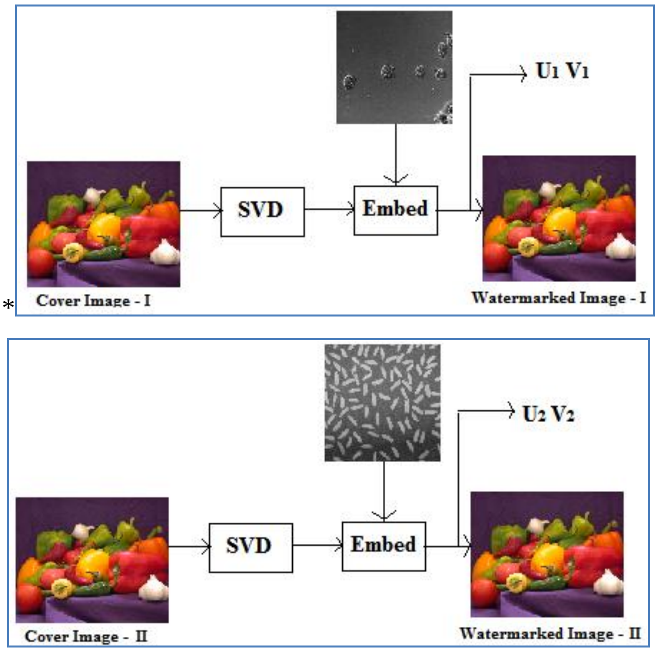


Figure 2 Embedding of watermark.

Zhang and Li in [13]shown that the orthogonal matrices U and V preserve most of thedataas they characterizeEigen vectors of the respective SVs. When inverse SVD is applied,Eigen vectors play a significant role in extraction. Thus if any singular matrix is utilizedalong with Eigen vectors it will produce the correlated output as an alternative of the actual output. Thecorrelation will be high if the unmatched SVs will be roughly equal to the originalSVs. So it gives rise to large number of false-positives during watermark detectionand also presents a security hazard.

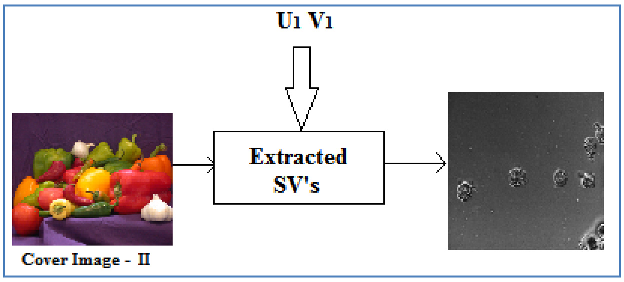


Figure 3 Extraction of watermark.

This risk can be seen as problem of unauthorized embeddingwherever an attacker may use his own set of Eigen vectors throughout watermark extractionand claims false possession. To overcome these disadvantages, a signature-based authentication tool for U and V matrices was presented in this paper. Orthogonal matrices (U and V) are authenticatedbefore combining them with SVs to generate watermark image. A unique signatureconforming to the orthogonal matrices are created and embedded into the cover imagealong with the watermark. The decoder extracts these signatures, authenticates orthogonal matricesand then proceeds with the extraction of watermark. This will safeguard a correct mapping amongthe SVs and orthogonal matrices.

a. Generation of signature

Digital signature of the orthogonal matrices is a unique binary string made through a hashingfunction. In addition, the digital signature must be random, so that an attacker can’t predictthem. Digital signature for the orthogonal matrices is generated as follows.

Proposed algorithm:

i. Add the column of orthogonal matrices and create 1-D array.
ii. Based on the threshold, map the array values into corresponding binary digits.
iii. By XORing the binary digits make the signature for the given orthogonal matrices.

Threshold value plays an important role while mapping and it is used to randomize the mapping,improving the security.

b. Proposed authentication scheme

Embedded signature should remain robust against processing manipulation. Alteration in signaturebits at decoder roots authentication to miscarry. Therefore, signature bits must be embedded into highenergy region for better robustness. The length of the signature is kept small to minimizechanges in the high energy coefficients. Signature should persist robust against wide range ofattacks hence one set of signature bits are embedded into LL4 and another set is embedded intoHH4 band to ensure retrieval from at least one of the band. The algorithm for embedding andextracting the signature is given below.

Signature embedding:

i. Produce the signature of N bits for the U and V matrices of watermark.
ii. Using Haar wavelet, decompose the cover image into 4 subbands: LL, HL, LH, and HH.Further decompose LL band to the 4th level.
iii. Select N random coefficient from LL4 and HH4 band with the help of secret key. Convertthe integer part into the binary code of L bits.
iv. Replace the n^{th} bit of the coefficient with signature bit and then convert the binary code toits decimal representation.
v. Apply the inverse DWT with modified LL4 and HH4 band coefficients.

Signature extraction:

i. Using DWT, decompose the watermarked image into 4 sub-bands: LL, HL, LH, and HHwith help of Haar wavelet and further decompose LL band to the 4th level.

IJARSE
ISSN: 2319-8354

ii. Select N random coefficient from LL4 and HH4 band with the help of shared secret key.Convert the integer part of selected coefficient into the binary code of L bits.

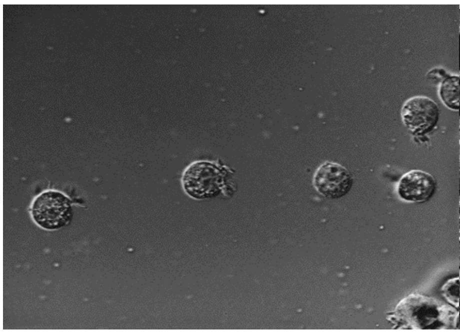
iii. Extract the n^{th} bit from the coefficient to extract the signature.

iv. Generate signature using U and V matrices of the original watermark at the receiver andcompare it with extracted signature. If they match, authenticate U and V matrices and usethem in watermark estimation.

In this work an 8-bit signature is produced for the authentication. Certain coefficients from LL4 and HH4were changed to 16 bit binary number and 10th most significant bit position is replaced withsignature bits.This authentication mechanism is employed in parallel with the watermarking scheme.Figures 4a and b show the block diagram of the proposed scheme. The encoder will embed the watermark and signature bits according to the proposed scheme.The decoder extracts the signature and matches it with the regenerated signature for authentication of U and V matrices. If matching criteria is satisfied, then decoder will continue estimating watermark.

VI.SIMULATION RESULTS

In this section the simulation results of the proposed technique is presented. The images in Figure4 are considered as the cover image and watermark respectively.




International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.03, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

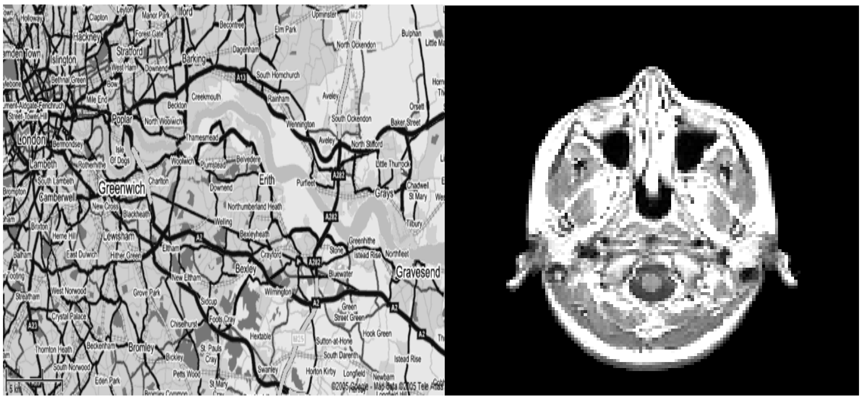
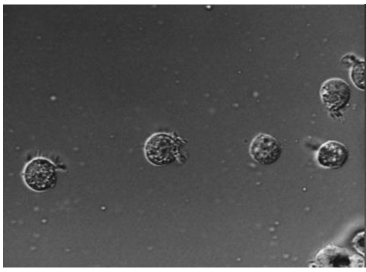
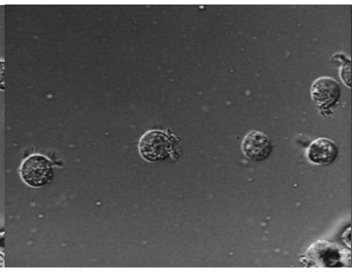
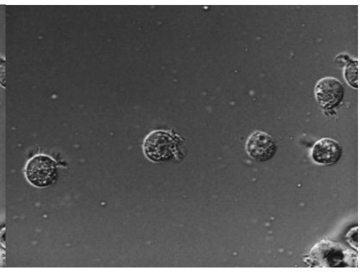


Figure4 Cover image and Watermark

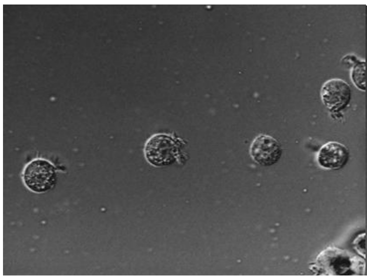
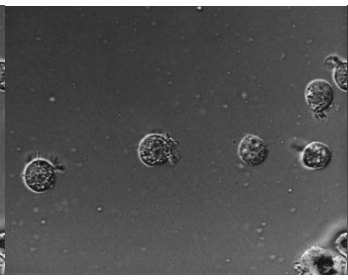
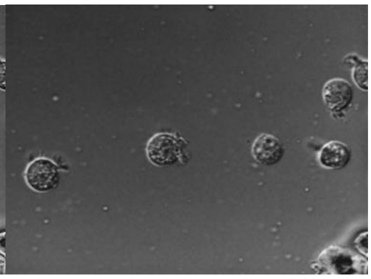
The proposed technique is used to hide the watermark in the cover image. On the watermarked image different attacks are applied and the watermark was extracted. The attacks considered in this work are noise effects of Gaussian, Poisson, Speckle and Salt & Pepper, compression and blurring. In the Figure5 the extracted images with different attacks are shown along with the PSNR and MSE values.

No Attack Gaussian Noise Poisson Noise

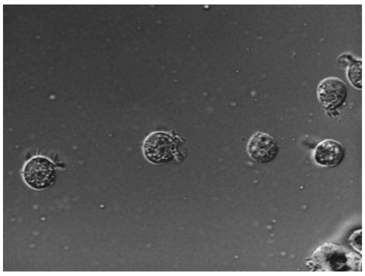
PSNR = 52.2524dB PSNR = 36.9737dB PSNR = 41.8670dB

Speckle Noise Salt & Pepper Noise Blurring

PSNR = 46.8200dB PSNR = 43.0782dB PSNR = 42. 4186dB

Compression



PSNR = 38.5886dB

Figure 5 Extracted watermark after different attacks

The table I shows the performance of signature based technique on different images.

TABLE I: Performance of signature based technique

	Map		**Bacteria**		**Concordortho**		**MRI**	
	MSE	**PSNR**	**MSE**	**PSNR**	**MSE**	**PSNR**	**MSE**	**PSNR**
No Attack	1.36	46.79	0.39	52.25	0.64	50.07	0.10	58.29
Gaussian	12.92	37.02	13.05	36.97	13.08	36.97	8.95	38.61
Poisson	15.95	36.10	4.23	41.87	7.87	39.17	1.23	47.24
Speckle	6.51	39.99	1.35	46.82	2.85	43.58	0.36	52.55
Salt & Pepper	2.94	43.45	3.20	43.08	3.64	42.52	6.20	40.21
Blurring	580.60	20.49	3.73	42.42	56.69	30.60	43.90	31.71
Compression	8.88	38.65	9.00	38.59	8.99	38.59	9.00	38.59

VII.CONCLUSIONS

In this paper a novel robust watermarking scheme was proposed using DWT and SVD. A standard DWT-SVD based watermarking scheme was used. The HH subband was used to hold the watermark. In the standard DWT-SVD based watermarking scheme the authentication problem was explained. A signature based resolution to the authentication problem was proposed. The signature developed in this algorithm was specific to the SVD coefficients at the instant. The signature was embedded into the fourth level decomposition of LL of the cover image. Based on a secret key four coefficients are selected and then replaced with the signature. By using similar steps on watermarked image the signature will be extracted. If the signature is matched then U and V will be used to extract the watermark from the watermarked image. The simulation results have shown that the watermark was sustained a number attacks.

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