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ADAPTIVE IMAGE WATERMARKING USING DISCRETE WAVELET TRANSFORM, SINGULAR VALUE DECOMPOSITION AND AUTOMORPHISM

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Abstract. Watermarking is a method to hide the image efficiently into any covering object (image in our case) so no intruder can interpret it by any means. Proposed work is a new design of image watermarking which include pre-processing of cover image with Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD). Proposed work using an alphanumeric key which initially modifies the watermark using simple 'XOR' operation, and at the receiver end this key must be there so that receiver can extract the watermark. Proposed work is also using torus Automorphism which initially changes the watermark into a scramble format which cannot be recognised as original watermark.

Keywords. DWT***:*** Discrete Wavelet Transform, SVD: Singular Value Decomposition, TA: Torus Automorphism, AS: Arnold scrambling, LL: approximate band, LH: Vertical Band, HL: Horizontal band, HH: diagonal detail band.

INTRODUCTION

There are several image watermarking schemes with a challenge to provide both perceptual quality as well as robustness against attacks, as these two measures conflict with each other. According to the domain of embedding, there are two types of watermarking schemes - spatial domain and transform domain based watermarking schemes. Spatial domain watermarking schemes embed watermark by modifying pixels of host image, while transform domain schemes embed watermark in transform domain coefficients. In transform domain, DWT and DCT are mainly used for its multi-resolution and energy compaction properties respectively. Based on extraction process, there are again two types of watermarking schemes blind and non-blind watermarking schemes. Non- blind watermarking scheme requires the host image for extraction of watermark while blind schemes need not.

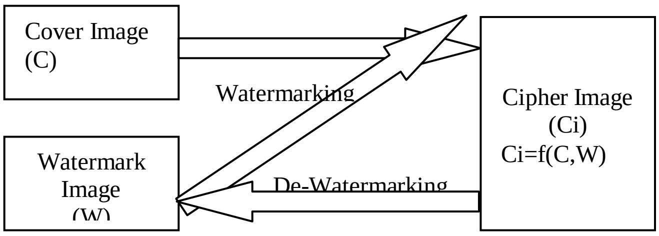

Figure 1. Watermarking hiding scenario.

The major problems of secure data communication are as follow:-
Watermarking is an overhead for communication system, it secures data. In watermarking the size of cover image must be very high than watermark image. We cannot use same algorithm for all type of cover image and watermark. In watermarking the time for hiding watermark should be low enough so it does not disturb communication. First issue is to maintain balance between imperceptibility, robustness and capacity as increasing one factor adversely affects other and a good digital watermarking system possess above feature. To achieve good imperceptibility, watermark should be embedded in high frequency component whereas robustness occurs in low frequency component.

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METHODOLOGY

Proposed work is a new design of image watermarking which include first pre-processing of cover image with DWT and SVD. DWT based watermarking can be adaptive and as cover image changes, its frequencies also change so the watermark image also get hides at different locations and spread at different locations. SVD has been applied for hiding bits of watermark and SVD has been taken of 8x8 block which hide a single bit of watermark at 64 different singular values of each block, because of SVD impact all kind of communication attacks like modulation, noise, compression and filter can be avoided, Changing SVs slightly does not affect the quality of the signal and if quality of signal changes due to any other cause SVs still get slightly change as compare to other samples of signal. So if in communication some of SVs changes our singles bit which is hidden at 8x8=64 SVs locations still can be recovered. Proposed work using an alphanumeric key which initially modifies the watermark using simple 'XOR' operation, and at the receiver end this key must be there so receiver can extract the watermark. Proposed work is also using torus Automorphism which initially change the watermark into a scramble format which cannot be recognition as original watermark, this provides extra security of the watermark and if some intruder recover watermark from cover image, he will get a scramble watermark which will further needed to get in its original shape.

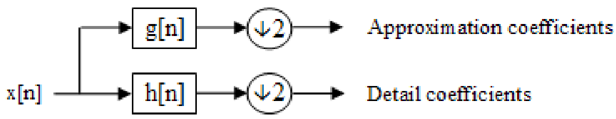

Figure 2. DWT HP and LP coefficient generation

ALGORITHM ADOPTED FOR WATERMARKING

Let C is the cover image of MxN size and W is the watermark image of PxQ size, DWT applied on 'C', proposed work use 'sym4' type wavelet for decomposition of Cover image

$$x(n)_L = \sum_{k=-\infty}^{\infty} x(k)g(2n-k) \qquad (1)$$

$$x(n)_H = \sum_{k=-\infty}^{\infty} x(k)h(2n-k) \qquad (2)$$

Where g and h coefficients taken from Sym4 filter coefficients. DWT2 is use for Images for two dimension DWT, hence $x(n)_L$ and $x(n)_H$ further need to filtered as below

$$x(n)_{LL} = \sum_{k=-\infty}^{\infty} x(n)_L g(2n-k) \qquad (3)$$

$$x(n)_{LH} = \sum_{k=-\infty}^{\infty} x(n)_L h(-k) \qquad (4)$$

$$x(n)_{HL} = \sum_{k=-\infty}^{\infty} x(n)_H g(2n-k) \qquad (5)$$

$$x(n)_{HH} = \sum_{k=-\infty}^{\infty} x(n)_H h(2n-k) \qquad (6)$$

Equation (3), (4), (5) and (6) are the level one DWT decomposition

$$x(n)_{HHH} = \sum_{k=-\infty}^{\infty} x(n)_{HH} g(2n-k) \qquad (7)$$

$$x(n)_{HHL} = \sum_{k=-\infty}^{\infty} x(n)_{HH} h(2n-k) \qquad (8)$$

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$$x(n)_{LL1} = \sum_{k=-\infty}^{\infty} x(n)_{HHL} g(2n-k) \quad (9)$$

$$x(n)_{LH1} = \sum_{k=-\infty}^{\infty} x(n)_{HHL} h(2n-k) \quad (10)$$

$$x(n)_{HL1} = \sum_{k=-\infty}^{\infty} x(n)_{HHH} g(2n-k) \quad (11)$$

$$x(n)_{HH1} = \sum_{k=-\infty}^{\infty} x(n)_{HHH} h(2n-k) \quad (12)$$

Equation (9), (10), (11) and (12) are the level two DWT decomposition

$$x(n)_{HH1H} = \sum_{k=-\infty}^{\infty} x(n)_{HH1} g(2n-k) \quad (13)$$

$$x(n)_{HH1L} = \sum_{k=-\infty}^{\infty} x(n)_{HH1} h(2n-k) \quad (14)$$

$$x(n)_{LL2} = \sum_{k=-\infty}^{\infty} x(n)_{HH1L} g(2n-k) \quad (15)$$

$$x(n)_{LH2} = \sum_{k=-\infty}^{\infty} x(n)_{HH1L} h(2n-k) \quad (16)$$

$$x(n)_{HL2} = \sum_{k=-\infty}^{\infty} x(n)_{HH1H} g(2n-k) \quad (17)$$

$$x(n)_{HH2} = \sum_{k=-\infty}^{\infty} x(n)_{HH1H} h(2n-k) \quad (18)$$

Equation (15), (16), (17) and (18) are the level three DWT decomposition

Size of $x(n)_{HH}$ is (MxN)/4 size and $x(n)_{HH1}$ is (MxN)/16 and $x(n)_{HH2}$ is (MxN)/64, Let size of $x(n)_{HH2}$ is RxS where R=M/8 and S=N/8. SVD taken of 8x8 block of $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ *and* $x(n)_{HH2}$ means at each DWT decomposed level $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ *and* $x(n)_{HH2}$ will have total RxS/64 SVD. We get total 4 $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ *and* $x(n)_{HH2}$ components after three level DWT decomposition. Means (RxS/64)x4 watermark bit can be hide. And as known R=M/8 and S=N/8

$$\begin{gathered} total\ numbet\ of\ watermark\ bit\ that\ can\ be \\ hide\ in\ cover = \frac{RxSx4}{64} = \frac{MxNx4}{8x8x64} = \frac{MxN}{1024} \end{gathered}$$

Here we are explaining the Calculation of SVD for $x(n)_{HH2}$ only although it has been computed for all 8x8 block of $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ *and* $x(n)_{HH2}$

Let B1 is the first 8x8 block of $x(n)_{HH2}$. The singular value decomposition of matrix B1 is a factorization of the form USV^T, where U is an 8x8 real matrix, S is a 8x8 rectangular diagonal matrix with non-negative real numbers on the diagonal, and V is an 8x8 real or complex unitary matrix. The diagonal entries σ_i of S are known as the singular values of B1. The columns of U and the columns of V are called the left-singular vectors and right-singular vectors of B1, respectively.

$$W1 = B1xB1^T$$

For a unique set of eigenvalues the determinant of the matrix (W1-$\boldsymbol{\sigma_i}$) must be equal to zero. Thus from the solution of the characteristic equation, |W1-$\boldsymbol{\sigma_i}$|=0 we obtain eight singular values of $\boldsymbol{\sigma_i}$ $\boldsymbol{where\ i = 1, 2, \ldots .. 8}$

$$(W1 - \sigma_i I) = 0 \qquad (19)$$

$$S = \begin{matrix} \sigma 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma 3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma 5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma 6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma 7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma 8 \end{matrix}$$

And if values of $\boldsymbol{\sigma_i}$ again put into equation (20) we obtain x1, x2, x3, x4, x5, x6 x7 and x8 value

$$(W1 - \sigma_i I)x = 0 \qquad (20)$$

$$U = \begin{matrix} x1 & -x2 & -x3 & -x4 & -x5 & -x6 & -x7 & -x8 \\ x8 & x1 & -x2 & -x3 & -x4 & -x5 & -x6 & -x7 \\ x7 & x8 & x1 & -x2 & -x3 & -x4 & -x5 & -x6 \\ x6 & x7 & x8 & x1 & -x2 & -x3 & -x4 & -x5 \\ x5 & x6 & x7 & x8 & x1 & -x2 & -x3 & -x4 \\ x4 & x5 & x6 & x7 & x8 & x1 & -x2 & -x3 \\ x3 & x4 & x5 & x6 & x7 & x8 & x1 & -x2 \\ x2 & x3 & x4 & x5 & x6 & x7 & x8 & x1 \end{matrix}$$

And if

$$W2 = B1^T x B1$$
$$(W2 - \sigma_i I)x = 0 \qquad (\mathbf{21})$$

And if values of $\boldsymbol{\sigma_i}$ again put into equation (21) we obtain x1, x2, x3, x4, x5, x6 x7 and x8 value

$$V = \begin{matrix} x1 & x2 & x3 & x4 & x5 & x6 & x7 & x8 \\ -x8 & x1 & x2 & x3 & x4 & x5 & x6 & x7 \\ -x7 & -x8 & x1 & x2 & x3 & x4 & x5 & x6 \\ -x6 & -x7 & -x8 & x1 & x2 & x3 & x4 & x5 \\ -x5 & -x6 & -x7 & -x8 & x1 & x2 & x3 & x4 \\ -x4 & -x5 & -x6 & -x7 & -x8 & x1 & x2 & x3 \\ -x3 & -x4 & -x5 & -x6 & -x7 & -x8 & x1 & x2 \\ -x2 & -x3 & -x4 & -x5 & -x6 & -x7 & -x8 & x1 \end{matrix}$$

U, S and V computed for each 8x8 block of all level three DWT decomposed $\boldsymbol{x(n)_{LL2}}$, $\boldsymbol{x(n)_{LH2}}$, $\boldsymbol{x(n)_{L22}}$ ***and*** $\boldsymbol{x(n)_{HH2}}$, As explain above.

$$U_{x(n)_{LL2}}, S_{x(n)_{LL2}}, V_{x(n)_{LL2}} = SVD(x(n)_{LL2}) \quad (22)$$
$$U_{x(n)_{LH2}}, S_{x(n)_{LH2}}, V_{x(n)_{LH2}} = SVD(x(n)_{LH2}) \quad (23)$$
$$U_{x(n)_{HL2}}, S_{x(n)_{HL2}}, V_{x(n)_{HL2}} = SVD(x(n)_{HL2}) \quad (24)$$
$$U_{x(n)_{HH2}}, S_{x(n)_{HH2}}, V_{x(n)_{HH2}} = SVD(x(n)_{HH2}) \quad (25)$$

On the other hand W is the watermark image of PxQ size will logical XOR with the 8 bit key 'K'

W1= (W xor K) (26)

The Torus Automorphism disarranges the watermark bits equally and randomly before embedding and reconstructing it before extraction. Torus Automorphism is one of the kinds of a dynamic system. A dynamic system, changes the stats s when time t changes. Where p is a user input, it basically swap the pixel positions.

$$(x_{i+t,j+t}) \leftrightarrow x_{i,j} \; where \; t = \sqrt{p^2 - i^2} \quad (27)$$

W2=torus(W1) with p=2
W3=torus(W2) with p=4
W4=torus(W3) with p=8
W5=torus(W4) with p=16
W6=torus(W5) with p=32

This is how scrambling done on watermark image W1 and W6 is developed after five time Torus Automorphism. Each samples of W6 converted into binary and an binary sequence generated

BW6=dec2bin(W6,8) *(28)*

Now BW6 is the watermark which is need to be hide inside the DWT and SVD decamped cover images which are shown in equations (22), (23), (24) and (25)

$$MS_{x(n)_{LL2}}, = lsb(S_{x(n)_{LL2}}) xor \; BW_i \quad (29)$$
$$MS_{x(n)_{LH2}}, = lsb(S_{x(n)_{LH2}}) xor \; BW_{i+1} \quad (30)$$
$$MS_{x(n)_{HL2}}, = lsb(S_{x(n)_{HL2}}) xor \; BW_{i+2} \quad (31)$$
$$MS_{x(n)_{HH2}}, = lsb(S_{x(n)_{HH2}}) xor \; BW_{i+3} \quad (32)$$

Equation (29), (30), (31) and (32) develop modified S components of SVD

$$(x(n)_{NLL2}) = U_{x(n)_{LL2}} * MS_{x(n)_{LL2}} * V_{x(n)_{LL2}}{}^T$$
$$(x(n)_{NLH2}) = U_{x(n)_{LH2}} * MS_{x(n)_{LH2}} * V_{x(n)_{LH2}}{}^T$$
$$(x(n)_{NHH2}) = U_{x(n)_{HH2}} * MS_{x(n)_{HH2}} * V_{x(n)_{HH2}}{}^T$$

$$(x(n)_{NHL2}) = U_{x(n)_{HL2}} * MS_{x(n)_{HL2}} * V_{x(n)_{HL2}}{}^T$$

IDWT 3rd level

$$x(n)_{NHH1L} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NLL2} \pm x\left(\frac{n}{2}\right)_{NLH2} \right\}$$
$$x(n)_{NHH1H} = \sum_{n=-\infty}^{\infty} \{ x\left(\frac{n}{2}\right)_{NHL2} \pm x\left(\frac{n}{2}\right)_{NHH2} \}$$
$$x(n)_{NHH1} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NHH1N} \pm x\left(\frac{n}{2}\right)_{NHH1H} \right\}$$
$$x(n)_{NHHH} = \sum_{n=-\infty}^{\infty} \{ x\left(\frac{n}{2}\right)_{NHH1} \pm x\left(\frac{n}{2}\right)_{HL1} \}$$

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$$x(n)_{HHL} = \sum_{n=-\infty}^{\infty} \left\{x\left(\frac{n}{2}\right)_{LL1} \pm x\left(\frac{n}{2}\right)_{LH1}\right\}$$

$$x(n)_{NHH} = \sum_{n=-\infty}^{\infty} \{x\left(\frac{n}{2}\right)_{NHHH} \pm x\left(\frac{n}{2}\right)_{HHL}\}$$

$$x(n)_{NH} = \sum_{n=-\infty}^{\infty} \left\{x\left(\frac{n}{2}\right)_{NHH} \pm x\left(\frac{n}{2}\right)_{HL}\right\}$$

$$x(n)_{L} = \sum_{n=-\infty}^{\infty} \{x\left(\frac{n}{2}\right)_{LL} \pm x\left(\frac{n}{2}\right)_{LH}\}$$

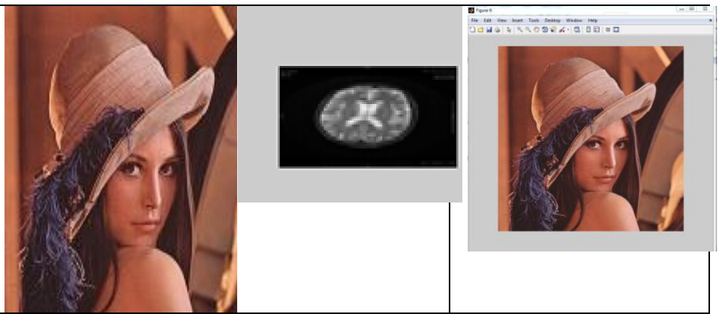
$$x(n)_{N} = \sum_{n=-\infty}^{\infty} \{x\left(\frac{n}{2}\right)_{L} \pm x\left(\frac{n}{2}\right)_{NH}\}$$

$\boldsymbol{x(n)_N}$ is the final cipher image which will have watermark image hidden inside i

BLOCK DESCRIPTION

Step 1: At first step the image has been taken through MATLAB and then in the MATLAB environment it gets converted into pixels form (integer numbers).
the 64 bit Key.

Results :



Cover image	Watermark image	Cipher image

Figure 3. Selected cover image (1) and watermark image (2) and cipher image developed (3)

If Where D is cipher image, C is cover image, len is length of cover image then

MSE= (D – C)^2/ Len,
SNR= 10 log 10 (256^2/MSE),
BER = sum of (Data XOR Cipher) / (Len x 8)

Observe Results test cover image of Lena (512x512, 712 kb) and the cover images of 60x60 (4kb), 95x95 (8kb) and 128x128 (12 kb)

Table 1 observe results for cover Lena image with different size watermark image

Cover Size	Watermark size	SNR	MSE	BER
512x512/ 712kb	60x60/4kb	80.57	0.27	0.2444
512x512/ 712kb	95x95/8kb	70.99	1.20	0.78
512x512/712kb	128x128/12kb	68.97	1.63	0.84

COMPARATIVE RESULTS

The comparative results are comparison between proposed method watermarking with available method of watermarking and it can be done on the behalf of SNR observe by the different methods for the standard cover image of 512x152 and watermark of 128x128 size.

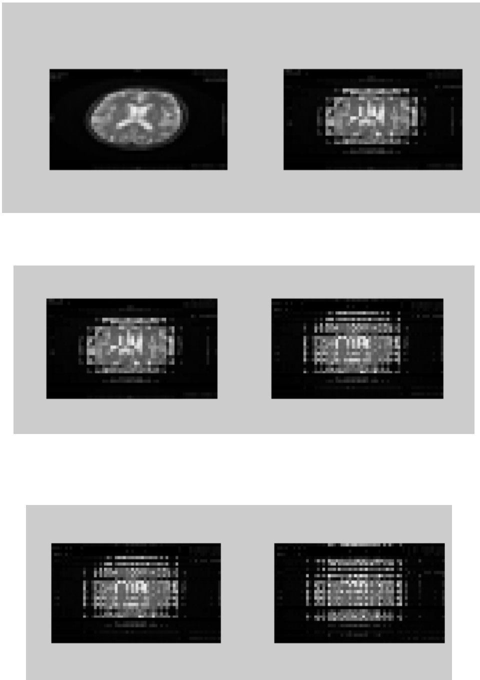


Figure 6. Watermark image torus Automorphism level

Table 2. Comparative result

	AUTHOR	PSNR
1.	Po-Yueh Chen et al	46.74dB
2.	Tanmay Bhattacharya et al	27.3850 dB
3.	Archana S. Vaidya et al	29.64 dB
4.	Hyung -Shin Kim et al	36 dB
5.	Mayank Awasthi et al	49.91 dB
6.	Nallagarla.Ramamurthy et al	51.8 dB
7.	G. Rosline Nesa Kumari et al	49.48 dB
8.	Krishna Rao Kakkirala et al	52.56 dB
9.	Aniket Roy et al	51.9541 dB
10	Amra siddiqui et al	41.92 dB
11	Zhi Zhang et al	62.28 dB
12	Proposed work	PSNR 68.97 dB

From the comparative results above we can clearly observe that the proposed work has best SNR among all available work.

CONCLUSION

Watermarking is an approach to hide the data (image in our case) efficiently into any covering object (image in our case) and it should restrict any intruder cannot interpret it by any means, it can be concluded on the basis of literature work that available methods are good in watermarking but there are still some problems with those techniques and that can be improve. . It can be concluded that DWT is the best suited method for adaptive watermarking and SVD is the method which best suited for lossless and attack free communication.

The original objective of the thesis work was to develop an optimised technique for hiding image and data inside cover image also to reduce the amount of data on channel while stenograph data transmission which has been achieved. The problem with watermarking is that it requires lots of data means another bigger image for sending some small watermark image, proposed work achieved that same size of watermark can be transmitted with small size of cover image as achieved SNR is better than available work.

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