

Discrete Wavelet Transform, Singular Value Decomposition and Automorphism based adaptive Image watermarking with high PSNR

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Abstract: Watermarking is a method to hide the image efficiently into any covering object (image in our case) so any intruder cannot interpret it by any means. Proposed work is a new design of image watermarking which include pre-processing of cover image with Discrete Wave 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 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. The work is been design and tested on MATLAB 2013 simulator.

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

I-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.

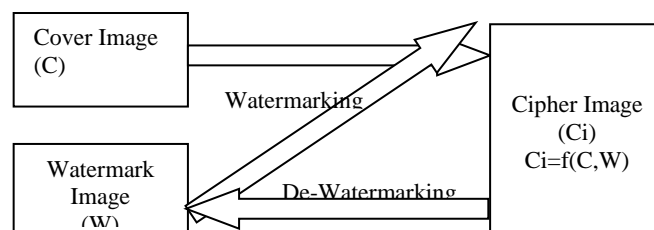


Figure 1 watermarking hiding scenario

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 effect on 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.

II-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 is been applied for hiding bits of watermark and SVD is 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

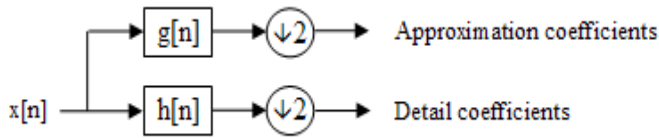


Figure 2 DWT HP and LP coefficient generation

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.

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

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

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

Where g and h coefficients taken from the table 3.1. DWT2 is use for Images for two dimension DWT, hence $x(n)_L$ and $x(n)_H$ further need to filtered as below

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Size of $x(n)_{HH}$ is (MxN)/4 size and $x(n)_{HH1}$ is

Sym	$h_0 = -0.0757657148,$	$g_0 = -0.0322231006,$
4	$h_1 = -0.0296355276$	$g_1 = -0.0126039673$
	$h_2 = 0.4976186676,$	$g_2 = 0.0992195436,$
	$h_3 = 0.8037387518$	$g_3 = 0.2978577956$
	$h_4 = 0.2978577956,$	$g_4 = -0.8037387518,$
	$h_5 = -0.0992195436$	$g_5 = 0.4976186676$
	$h_6 = -0.0126039673,$	$g_6 = 0.0296355276,$
	$h_7 = 0.0322231006$	$g_7 = -0.0757657148$

(MxN)/16 and $x(n)_{HH2}$ is (MxN)/64, Let size of

$x(n)_{HH2}$ is $R \times S$ where $R=M/8$ and $S=N/8$. SVD taken of 8×8 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 $R \times S/64$ SVD. We total 4 $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ and $x(n)_{HH2}$ components after three level DWT decomposition. Means $(R \times S/64) \times 4$ watermark bit can be hide. And as known $R=M/8$ and $S=N/8$

$$\text{total number of watermark bit that can be hide in cover} = \frac{R \times S \times 4}{64} = \frac{M \times N \times 4}{8 \times 8 \times 64} = \frac{M \times N}{1024}$$

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

Let $B1$ is the first 8×8 block of $x(n)_{HH2}$. the singular value decomposition of an 8×8 real matrix $B1$ is a factorization of the form USV^T , where U is an 8×8 real matrix, S is a 8×8 rectangular diagonal matrix with non-negative real numbers on the diagonal, and V is an 8×8 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.

$$W1 = B1x B1^T \\ (W1 - \sigma_i I) = 0 \quad (19)$$

$$S = \begin{matrix} \sigma_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma_8 \end{matrix}$$

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

And if values of σ_i again put into equation (20) we obtain $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ and x_8 value

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

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

And if

$$W2 = B1^T x B1 \\ (W2 - \sigma_i I)x = 0 \quad (21)$$

And if values of σ_i again put into equation (21) we obtain $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ and x_8 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 8×8 block of all level three DWT decomposed $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ and $x(n)_{HH2}$. As explain above.

$$U_{x(n)_{LL2}}, S_{x(n)_{LL2}}, V_{x(n)_{LL2}} = SVD(x(n)_{LL2}) \quad (22)$$

$$U_{x(n)_{LH2}}, S_{x(n)_{LH2}}, V_{x(n)_{LH2}} = SVD(x(n)_{LH2}) \quad (23)$$

$$U_{x(n)_{HL22}}, S_{x(n)_{HL22}}, V_{x(n)_{HL22}} = SVD(x(n)_{HL22}) \quad (24)$$

$$U_{x(n)_{HH2}}, S_{x(n)_{HH2}}, V_{x(n)_{HH2}} = SVD(x(n)_{HH2}) \quad (25)$$

On the other hand W is the watermark image of $P \times Q$ size will logical XOR with the 8 bit key 'K'

$$W1 = (W \text{ xor } K) \quad (26)$$

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.

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

$$W2 = \text{torus}(W1) \text{ with } p=2$$

$$W3 = \text{torus}(W2) \text{ with } p=4$$

$$W4 = \text{torus}(W3) \text{ with } p=8$$

$$W5 = \text{torus}(W4) \text{ with } p=16$$

$$W6 = \text{torus}(W5) \text{ with } p=32$$

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

$$BW6 = dec2bin(W6, 8) \quad (28)$$

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)

$$MS_{x(n)_{LL2}} = lsb(S_{x(n)_{LL2}}) xor BW_i \quad (29)$$

IDWT 3rd level

$$x(n)_{NHH1L} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NLL2} \pm x\left(\frac{n}{2}\right)_{NLH2} \right\}$$

$$x(n)_{NHH1H} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NHL2} \pm x\left(\frac{n}{2}\right)_{NHH2} \right\}$$

$$x(n)_{NHH1} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NHH1N} \pm x\left(\frac{n}{2}\right)_{NHH1H} \right\}$$

$$x(n)_{NHHH} = \sum_{n=-\infty}^{\infty} \left\{ x\left(\frac{n}{2}\right)_{NHH1} \pm x\left(\frac{n}{2}\right)_{HL1} \right\}$$

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

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

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

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

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

$x(n)_N$ is the final cipher image which will have watermark image hidden inside it.

Block description: Step 1: At first step the image is been taken through MATLAB and then in the MATLAB environment it gets converted into pixels form (integer numbers)

Step 2: For the data hiding as it is an analytical approach we required to convert it into frequency cum time domain which is possible with proposed symlet-4 based Wavelet transform only there are many wavelets techniques are available so it was our decision to make that on behalf of our requirement of time or frequency resolution. If we choose 'type1' then very good frequency resolution and if we choose 'type8' then time resolution gets better so we have choose 'type4' wavelet which give adequate time and frequency resolution. After 3 level of image decomposition LH,

$$MS_{x(n)_{LH2}} = lsb(S_{x(n)_{LH2}}) xor BW_{i+1} \quad (30)$$

$$MS_{x(n)_{HL2}} = lsb(S_{x(n)_{HL2}}) xor BW_{i+2} \quad (31)$$

$$MS_{x(n)_{HH2}} = lsb(S_{x(n)_{HH2}}) xor BW_{i+3} \quad (32)$$

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

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

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

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

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

HL and HH components are taken because H component are less interpretable by human eye.

Step 3: After transform the highest frequency elements of LL2, LH2, HL2, and HH2 is decompose into blocks of 8x8 means 64 pixels as shown in figure above.

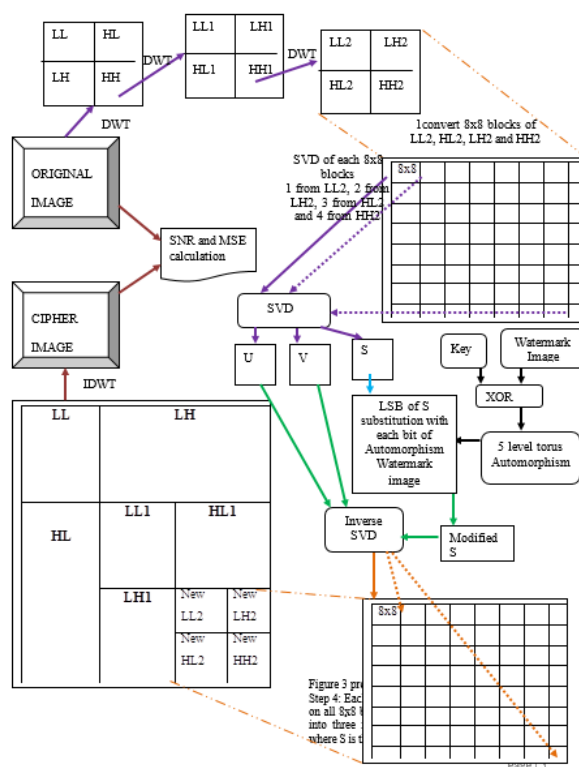


Figure 3 proposed watermarking

Step 4: Each 8x8 blocks taken and SVD performed on all 8x8 blocks, SVD decompose the each block into three individual blocks named U, S and V where S is the Eigen value of respective 8x8 blocks.

Step 5: The data Image (watermark) taken and all of its pixels gets XOR with the 64 bit Key.

Step 6: The modified 2D watermark (after XOR with Key) is provided to torus Automorphism which further scramble the image up-to five levels.

Step 7: The modified 2D watermark (after XOR with Key and Scramble through torus Automorphism) converted into binary 1D string this is requires because we are hiding binary values of data image.

Step 8: LSB of 'S' of each 8x8 block replace with a single binary bit of watermark binary string and this process done until all the binary digits does not get replace with LSB of 'S', to understand this process say first 8x8 block after SVD we will hide first binary value into its 'S' than for the next 8x8 block we will again perform the SVD and now second binary will get hidden into new 'S' and so on. One interesting thing is that this single binary bit scattered inside 64 pixels of 'S'. This is the major reason that SVD based hiding methods resist and robust against the channel attacks like noise, compression, modulation and filter.

Step 9: perform ISVD with modified S and old U and V' and also make a new LL2, LH2, HL2 and HH2 frequency component concatenating all ISVD's

Step 10: Performing IDWT for with new LL2, LH2, HL2 and HH2 and develop new HH1

Step 11: Performing IDWT for with new HH1 and old HL1, LL1 and LH1 and develop new HH

Step 12: Performing IDWT for with new HH and old HL, LL and LH and develop cipher Image

Step 13: Compute MSE and SNR between Original Image and Cipher Image.

The deciphering is process for as can be observed it exact reverse order than the ciphering process and our aim is to extract watermark not construct the original image so we did the process to have original data only.

ALGORITHM FOR EXTRACTION OF WATERMARK FROM CIPHER IMAGE:

Let X is the cipher image of MxN size DWT applied on 'X' Proposed work use 'sym4' type wavelet for decomposition of Cover image

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

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

DWT2 is use for Images for two dimension DWT, hence $x(n)_L$ and $x(n)_H$ further need to filtered as below

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

$$x(n)_{LH} = \sum_{k=-\infty}^{\infty} x(n)_L h(2n - k)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

We total 4 $x(n)_{LL2}$, $x(n)_{LH2}$, $x(n)_{HL22}$ and $x(n)_{HH2}$ components after three level DWT decomposition.

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

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

$$U_{x(n)_{LL2}}, S_{x(n)_{LL2}}, V_{x(n)_{LL2}} = SVD(x(n)_{LL2})$$

$$U_{x(n)_{LH2}}, S_{x(n)_{LH2}}, V_{x(n)_{LH2}} = SVD(x(n)_{LH2})$$

$$U_{x(n)_{HL2}}, S_{x(n)_{HL2}}, V_{x(n)_{HL2}} = SVD(x(n)_{HL2})$$

$$U_{x(n)_{HH2}}, S_{x(n)_{HH2}}, V_{x(n)_{HH2}} = SVD(x(n)_{HH2})$$

Y is the 1D binary sequence extracted from the 'S' obtain after SVD on LL2, HL2, HL2 and HH2

$$Y = \{1 \text{ LSB from all } 64 \text{ of } S_{x(n)_{LL2}},$$

$$2 \text{ LSB all } 64 \text{ of } S_{x(n)_{LH2}}, 3 \text{ LSB all } 64 \text{ of } S_{x(n)_{HL2}},$$

$$4 \text{ LSB all } 64 \text{ of } S_{x(n)_{HH2}}, \dots \dots \dots \}$$

$$nY = \text{Reshape}(Y, PxQ)$$

The Inverse Torus Automorphism nY to rearranges the watermark bits. P must be same as was at the time of watermark scrambling.

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

- $nY1 = \text{torus}(nY)$ with $p=32$
- $nY2 = \text{torus}(nY1)$ with $p=16$
- $nY3 = \text{torus}(nY2)$ with $p=8$
- $nY4 = \text{torus}(nY3)$ with $p=4$
- $nY5 = \text{torus}(nY4)$ with $p=2$

This is how inverse scrambling done on nY and new watermark $nY5$ is developed after five time inverse Torus Automorphism. At the last

$$Rx = (nY5) \text{ xor Key}$$

Here Rx is the final Recovered Watermark.

Block description:

Step 1: At first step the cipher image is been taken through MATLAB and then in the MATLAB environment it gets converted into pixels form (integer numbers)

Step 2: three level DWT and highest frequency elements of $LL2, LH2, HL2,$ and $HH2$ is decompose into blocks of 8×8 means 64 pixels as shown in figure above.

Step 4: Each 8×8 blocks taken and SVD performed on all 8×8 blocks, SVD decompose the each block into three individual blocks named U, S and V where S is the Eigen value of respective 8×8 blocks.

Step 5: LSB of all 64 elements of 'S' of each 8×8 blocks extracted found maximum similar binary appears at the LSB of 64 elements of 'S' and maximum consider as final binary bit. From the all 'S' develop a 1D binary sequence.

Step 6: reshape the binary bits at its original 2D size $P \times Q$ from 1D binary sequence.

Step 7: The modified 2D image is provided to inverse torus Automorphism which further re-arrange the samples of the image up-to five levels.

Step 8: The re-arranged image is XOR with the 64 bit Key which develop final watermark image.

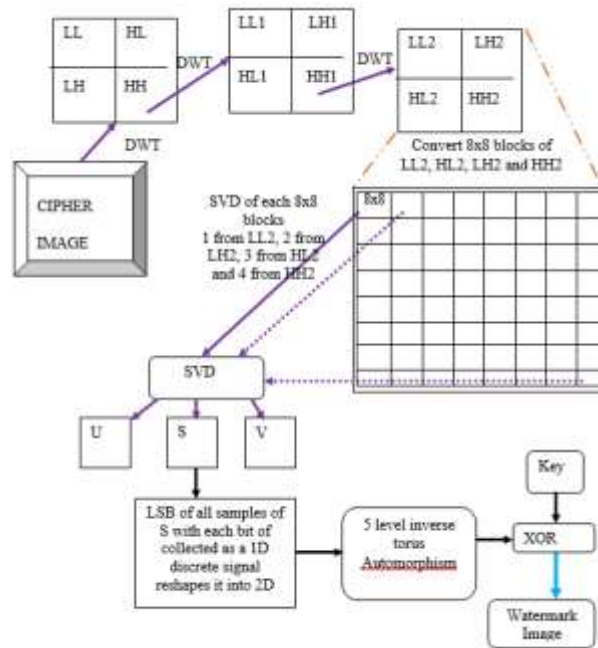


Figure 4 Proposed Method of watermark extraction

III-RESULTS

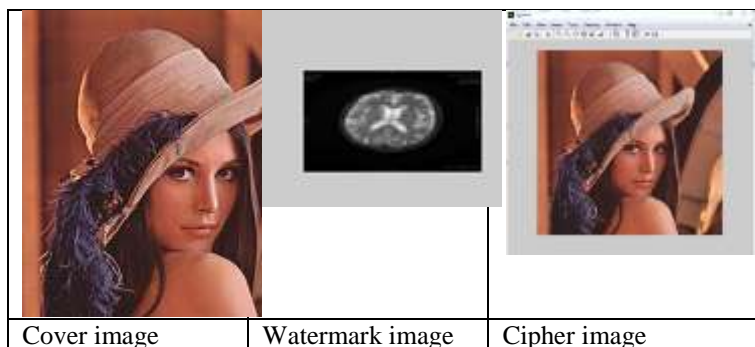


Figure 5 Selected cover image (1) and watermark images(2) and cipher image developed (3)

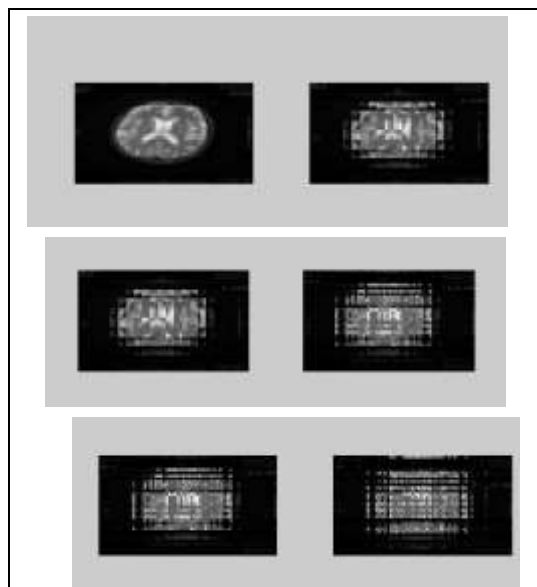


Figure 6 watermark image torus Automorphism level

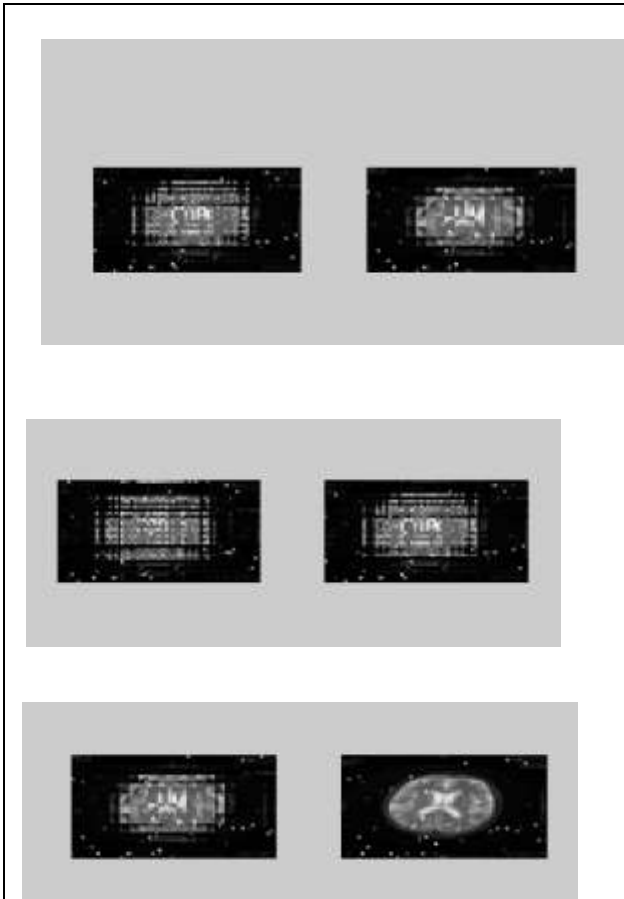


Figure 7 inverse torus Automorphism level-3 for watermark image extraction

If Where D is cipher image, C is cover image, len is length of cover image then
 $MSE = (D - C)^2 / Len,$
 $SNR = 10 \log_{10} (256^2 / MSE),$
 $BER = \text{sum of } (Data \text{ xor } Cipher) / (Len \times 8)$

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

Table 2 Comparative result

Sr.	AUTHOR	Output
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

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.

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

IV-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 do that 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 is 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 69.4.

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