Robust Secure SVD Based DCT – DWT Oriented Watermarking Technique for Image Authentication

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***Abstract*- The digital multimedia content authentication and copyright protection has become an important issue in the recent years. Digital Watermarking Technology has been proposed for the implementation of Digital Right Management. Digital watermarking is the process of embedding information into digital multimedia content such that the information can later be extracted or detected for a variety of purposes including copy prevention and authentication proof.**

A new SVD based and DCT-DWT oriented watermarking scheme is being proposed. This paper aims to achieve robustness with high perceptual transparency and low insertion ratio. The middle band DCT coefficients are chosen to achieve high robustness against JPEG compression. Robustness against other attacks is achieved by taking DWT of the DCT coefficients and the lowest frequency LL band of DWT is chosen for insertion. Insertion method in proposed technique uses SVD because slight variation of singular values does not change the visual perception of the image.

The experimental results show that the proposed technique is robust to both compression and image processing operations with low insertion ratio providing high perceptual transparency.

***Keywords*- digital multimedia content authentication, copyright protection Digital Watermarking Technology, Digital Right Management**

I. INTRODUCTION

The rapid increase in exchange and transmission of digital information through internet in the past two decades had demanded the need of technique which prevents the unauthorized users to tamper and distribute the data illegally and to provide the ways to authenticate users to prove their ownership on digital content. The technique used to achieve aforesaid objectives is Digital Watermarking. Digital watermarking is a technique of embedding one digital information into another digital information without changing the content of original information. The technology offers a means of conveying information inside a digital media file (for example, inside a photo, movie, or song). In Digital Image Watermarking the inserted watermark should not degrade the visual perception of an original image and must be robust. Therefore, it must withstand the attacks like JPEG compression, noise in the channel (during transmission), and comman image processing operations and shall be secure to any attempt made by unauthorized user to tamper the watermark. Digital Image watermarking is implemented in two ways i.e. in spatial domain and in frequency domain. In spatial domain where the pixel intensity value of the image is directly modified (LSB is modified to achieve high visual perception). The spatial domain techniques have proven to be less robust against attacks like JPEG compression. In frequency domain the signal or image is transformed into discreet coefficients which are then modified to insert the watermark. Inverse transform of the modified coefficients are taken to get back the original signal or image. Insertion in transformed domain proves to be more robust against attacks like JPEG compression as underlying concept behind compression uses transformation techniques (DCT and DWT).

A matrix decomposition technique known as SVD (Singular value decomposition) is widely used in image compression [1] and watermarking [2, 3] techniques. An SVD based watermarking scheme has been proposed in [3] in which the watermark is added to the SV(s) of the whole image or a part of it. A single watermark is used in this scheme which may be lost due to attacks. To overcome this work [4] on DWT-based multiple watermarking argues that inserting a visual watermark in both low and high valued coefficients results in a robust scheme for a wide range of attacks. Inserting in low valued coefficients increases the robustness with respect to attacks that have low pass characteristics like filtering, lossy compression and geometric distortions while making the scheme more sensitive to modifications of the image histogram, such as contrast/brightness adjustment, gamma correction, and histogram equalization. Watermarks inserted in middle and high valued coefficients are less robust to low-pass filtering, lossy compression and small geometric deformations of the image but are highly resilient with respect to noise addition, and nonlinear deformations of the gray scale. The technique [5] used DCT in place of DWT and inserted the watermark in four different frequency ranges by selecting coefficients in zigzag order. These technique produced good results when attacks were applies to it but it failed to achieve robustness to both compression and image processing tasks simultaneously when only one copy of watermark is inserted. Inserting four watermarks in single image makes the inserting ratio (of watermark) high.

The technique [6] proposed SVD based watermarking scheme, wherein the singular values is explored for inserting. The basic mechanism used was the quantization of the largest component with a filed constant integer, called Quantization coefficient. It states that tradeoff be achieved between transparency and robustness by varying the quantization coefficient. However, this method failed in extracting the watermark with zero error rate. The original watermark image and retrieved watermark image are not exactly similar. The technique [7] proposed a singular value decomposition based image watermarking scheme using quantization which had overcome the shortcomings of [6]. The watermarking technique in [8] proposed two notes on the SVD based watermarking algorithm. As per the proposal from [8] if the watermark is inserted in the columns of U matrix and rows of V^T, the perceptibility of the original image is improved. But, the proposed method was not robust to many attacks since watermark inserting is in U and V^T matrices. Magnitudes of U and V matrix elements are very small and so, even a small modification in either U or V components alters the watermark retrieval. Many of the schemes above suffer from either with the poor robustness or non-blind in nature.

The aforesaid techniques give rise to need of developing a new SVD based watermarking technique to achieve robustness against both compression and image processing tasks with low inserting ratio (By inserting only single watermark) and remove the trade-off between robustness and visual perception. To achieve these goals the proposed scheme combines the advantages of DCT (discrete cosine transform), DWT (discrete wavelet transform) and SVD (singular value decomposition). It first finds an appropriate area (lowest middle band frequency coefficients) of the image for watermark insertion using DCT and DWT transformations. Thus, the technique provides robustness against both compression and image processing tasks. The technique consequently inserts the watermark by implementing mathematical transform, singular value decomposition. The slight variation in singular values does not affect the visual perception of the image. Hence, solving the trade-off between robustness and perceptual transparency.

In the further proceeding section II describes the background of DCT, DWT and SVD and their properties. Proposed technique is presented in section III and experimental results are discussed in section IV. Section V concludes the paper with the future scope.

II. BACKGROUND

Discrete Cosine Transform is used to convert the Time domain signal into the Frequency domain signal. The 2-dimensional DCT of a given matrix gives the frequency coefficients in form of another matrix. Left topmost corner of the matrix represents the lowest frequency coefficients while the right bottom most corner represents the highest frequency coefficients. Using the DCT, an image is easily split up into pseudo frequency bands, and in this work watermark is inserted into the middle band frequencies because in all frequency domain watermarking schemes, there is a conflict between robustness and transparency. If the watermark is inserted in perceptually most significant components, i.e. low frequencies; the scheme tends to be robust to attacks but it is difficult to hide the watermark. On the other hand, if the watermark is inserted in perceptually insignificant components, i.e. high frequencies; it is easier to hide the watermark but the scheme is then less resistant to attacks [9]. Hence middle frequency range is suitable for watermark insertion.

Discrete wavelet transform divides an image into 4 coefficient images in the single level. Each coefficient image contains one of low frequency bands and high frequency bands. With an M×N image, 2-D DWT generates four M/2×N/2 coefficients: LL, LH, HL, and HH, where LL represents a low frequency band, LH a horizontal high frequency band, HL vertical high frequency band, HH a diagonal high frequency band. The low frequency band is utilized to the net level of DWT. In DWT, the most prominent information in the signal appears in high amplitudes and the less prominent information appears in very low amplitudes. Data compression can be achieved by discarding these low amplitudes. The wavelet transforms enables high compression ratios with good quality of reconstruction Wavelet transform is capable of providing the time and frequency information simultaneously, hence giving a time-frequency representation of the signal. DWT is believed to more accurately model aspects of the HVS (Human Visual System) as compared to the FFT or DCT. This allows to use higher energy watermarks in regions that the HVS is known to be less sensitive to. Inserting watermarks in these regions increases the robustness of watermark, additional impact on image quality. Experimentally it is being found that insertion in the LL portion of the DWT proves to be most robust against various kinds of attacks.

Singular value decomposition is a numerical technique used to diagonalize matrices in numerical analysis. It is an algorithm developed for a variety of applications.

Any matrix ‘M’ is decomposed into three sub matrices [u, s, v] such that:

$M=u*s*v^T$

Where ‘u’ and ‘v’ are the orthogonal matrices such that $u * u^T = I$ and $v * v^T = I$ where ‘I’ is the Identity matrix and ‘s’ is the diagonal matrix× ($s_1, s_2, s_3 \ldots\ldots\ldots s_N$) such that

$s_1>=s_2>=s_3\ldots\ldots\ldots s_{(N-1)}>=s_N$ [5].

These values are known as singular values, and matrices u and v are known as corresponding singular vectors [3]. The above decomposition is termed as Singular Value Decomposition.

A SVD, applied to the image matrix, provides singular values (diagonal matrix’s’) that represent the luminance or color intensity of the image while the matrices ‘u’ and ‘v’ represents the geometry of the image. It has been scientifically proved that slight variation in the singular values doesn’t change the visual perception of the image.

The work thus implements the SVD to provide better visual perception along with the robustness. The increased robustness is due to the stability of singular values. The stability of singular value indicates that, when there is a little disturbance with A, the variation of its singular value is not greater than 2-norm of disturbance matrix. 2-norm is equal to the largest singular value of the matrix. Singular values exhibit some more properties like rotation invariance, translation invariance, transposition invariance, etc. These all properties of SVD are much desirable in image watermarking.

III. PROPOSED TECHNIQUE

In the proposed method, the original image M (N × N) is watermarked with the watermark image W (N /4 × N/4). The transform domain is insured for the insertion mechanism. At first, DCT (M_C) of the original image M (N × N) is computed. The middle band coefficients are then collected to form a (N/2 × N/2) image matrix M_{MID}.

At next level, the DWT of the matrix M_{MID} is computed to give four sub-band matrices M_W (LL, LH, HL, HH). The singular value decomposition of the LL-Band matrix is performed to get U, S & V matrices where S is the diagonal matrix termed as singular value matrix and U & V are orthogonal matrices.

The watermark image W (N/4 × N/4) is taken and the DCT is computed to produce matrix W_C. Singular values of the matrix W_C then used to modify the S matrix computed previously. The detailed algorithm is given below:

Algorithm 1: Watermark insertion:

1. An original image of size (N × N) taken as input
2. Compute the DCT of the matrix M, M_c.
3. Form the square matrix of size (N/2 × N/2) from middle band DCT coefficients, M_{mid}.
4. Compute DWT of M_{mid}, M_w
5. Compute DCT of the watermark image, W_c.
6. Call procedure 1.2 to get modified LL band of M_W.
7. Using the modified LL band gets M_W*.
8. Compute M_{mid}* = inverse DWT of M_W*.
9. Reconstruct M_C using the matrix M_{mid}* and get M_C*.
10. Watermarked image M* = inverse DCT of M_C*.

Procedure (1.1) is used to embed the watermark using singular value modification.

Procedure (1.1): Insertion:

1. The SVD is performed on the LL-band matrix of M_{DWT}.

   $M_W = USV^T$
2. The DCT of the watermark (W_C matrix) is added to the SVs of the (*S* matrix).

   $MED = S + W\times \alpha$
3. The SVD is performed on the MED matrix.

   $MED = U_w S_w V^T$
4. Modified LL band is obtained using the singular values computed in last step.

   $M_W^* = US_wV^T$

Watermark extraction algorithm is given below:

Algorithm 2: Watermark extraction:

1. The square watermarked image of size (N × N) M* is taken as input.
2. Compute DCT of the matrix M, M_C*.
3. Form the square matrix of size (N/2 × N/2) from DCT middle band coefficients, M_{mid}*.
4. Compute DWT of the matrix M_{mid}*, M_W*.
5. Call procedure 1.2 to get the DCT of the watermark W_C*.
6. Watermark W* = inverse DCT of W_C*.

Procedure 1.2: Extraction:

1. The SVD is performed on the LL-band matrix of M_W*.

   $M_W^* = US^*V^T$ (1)

2. The matrix containing DCT of the watermark is computed.

   $MED^* = U_w S^* V_w^T$

3. The DCT matrix of the watermark is obtained by:

   $W_C^* = (MED^* - S)/\alpha$

IV. EXPERIMENTAL RESULTS AND DISCUSSION

To evaluate the performance of the proposed technique, the test case is being simulated by taking Lena 512 × 512 grayscale image (shown in Fig. 1 (a)) with 8 bits / pixel resolution for watermarking. The watermark image is of 128 × 128 size which is also grayscale and of 8 bits / pixel resolution. The value of the constant 'α' used is 0.03. The metric used to evaluate the performance of proposed technique is NCC ('Normalized cross co relation') which is defined as below:

$$NCC = \frac{\sum_i \sum_j W(i,j).\, W^*(i,j)}{\sum_i \sum_j (W(i,j))^2}$$

Where W (i, j) is the pixel values at the position (i, j) of the original content or image and W^* (i, j) is the pixel values at the position (i, j) of the image or content to which it is to be compared with original one, respectively.

Fig. 1 (a) Original Image (b) Watermark Image

Fig. 2 shows that visual perception of the watermarked image is high with NCC value 0.9999. Result shows that no significant distortion or visible changes occur in image after inserting the watermark. Also the extracted watermark is exactly similar to original watermark image with NCC value 0.9997. The performance of the proposed technique is tested in Matlab software version 7.0.

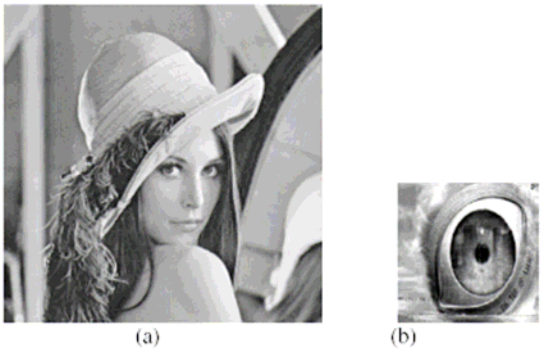

Fig. 2 (a) Watermarked Image, NCC = 0.9999 (b) Extracted Watermark without attacks, NCC = 0.9997

The attacks applied to the watermarked image to test the robustness of watermark are JPEG compression (80%, 60%, 40%, 30% and 20%), cropping, low pass filtering, medium pass filtering, rotation and modification. The extracted watermarks after applying various attacks are shown in Fig. 3. The NCC values of the extracted watermarks are shown in the Table 1.1.

The watermarked image is compressed using lossy JPEG compression. The percentage by which the watermarked image is compressed to test robustness are 80%, 60%, 40%, 30% and 20% where less percentage represents most compression and more degraded watermarked image. The results shows that the proposed technique is found to be robust even against JPEG 20% compression with NCC value 0.9076.

For low pass filtering attacks, a 3 × 3 mask with intensity value 0.1 is used. The medium pass filter is non linear spatial filter which is usually used to remove noise spikes from an image. The watermarked is attacked by medium pass filtering with a 3 × 3 mask. The above technique is found to be robust against filtering.

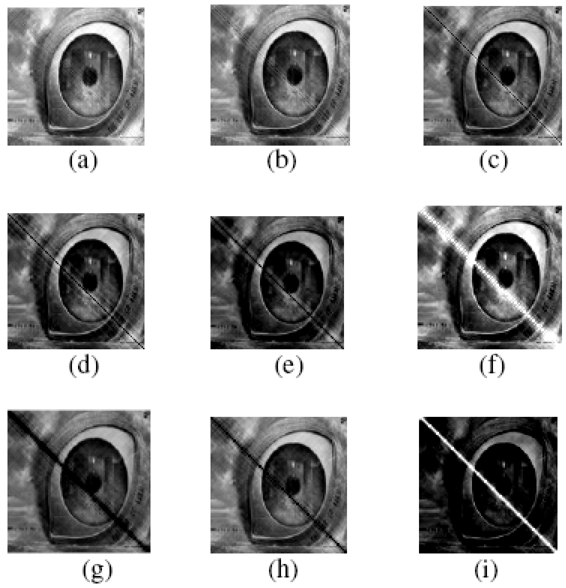

Fig. 3 Extracted Watermarks when attacks applied to watermarked Image (a) JPEG 80% (b) JPEG 60% (c) JPEG 40% (d) JPEG 30% (e) JPEG 20% (f) Cropping (g) Low pass filter (h) Medium Pass filter (i) Rotation

Fig. 4 (a) Modified Watermarked Image (b) Extracted watermark from modified Watermarked Image

The cropping operation deletes some portion of watermarked image. The extracted watermark is still robust with the NCC value 0.8420. In row column blanking attack 20 rows and 10 columns are eliminated from the watermarked image.

The watermarked image is rotated by 17^o the right with image size increased to 619 × 619 and then again resized to 512 × 512. The resizing operation initially increases the size of the image and then generates the original image by using an interpolation technique. This operation is a lossy operation and hence the watermarked image also looses some watermark information. In this experiment, initially the watermarked image size is increased from 512×512 to 619×619 by using the linear interpolation technique to accommodate the whole image after rotation. Later, its dimensions are reduced to 512×512. But the watermark extracted is still recognizable with NCC value 0.5180.

The above results are tabulated below:

TABLE 1.1
RESULTS OF PROPOSED TECHNIQUE

Attacks applied to the Watermarked Image	NCC value of extracted Watermark after applying attacks with Original Watermark
JPEG 80%	0.9945
JPEG 60%	0.9887
JPEG 40%	0.9634
JPEG 30%	0.9452
JPEG 20%	0.9076
Cropping	0.8420
Low pass filtering	0.8849
Medium Pass filtering	0.9265
Rotation	0.5180
Modification	0.7809

the DWT co efficient to provide robustness against the image processing tasks. These LL band DWT co efficients are the computed values of the middle band DCT coefficients which are robust against JPEG compression. Thus the scheme is able to provide robustness against both compression and image processing tasks. This is clarified by the experimental results. Since, only one watermark is inserted in the image, so the inserting ratio is also lowers (16:1). Since SVD is the method used for insertion (modifying singular values) and DWT coefficients are used the visual perception of the watermarked image is also not degraded. Thus, the proposed scheme is found to be robust against these attacks in descending order JPEG compression, medium pass filtering, low pass filtering, cropping and rotation with very low inserting ratio and high visual perception.

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