Robust watermarking based on DWT SVD

Anumol Joseph[1], K. Anusudha[2]
Department of Electronics Engineering, Pondicherry University, Puducherry, India
anumol.josph00@gmail.com, anusudhak@yahoo.co.in

***Abstract*— Digital information revolution has brought about many advantages and new issues. The protection of ownership and the prevention of unauthorized manipulation of digital audio, image, and video materials has become an important concern due to the ease of editing and perfect reproduction. Watermarking is identified as a major means to achieve copyright protection. It is a branch of information hiding which is used to hide proprietary information in digital media like photographs, digital music, digital video etc. In this paper, a new image watermarking algorithm that is robust against various attacks is presented. DWT (Discrete Wavelet Transform) and SVD (Singular Value Decomposition) have been used to embed two watermarks in the HL and LH bands of the host image. Simulation evaluation demonstrates that the proposed technique withstand various attacks.**

***Index Terms*— Discrete Wavelet Transform, Singular Value Decomposition, Peak Signal to Noise Ratio (PSNR)**

I. INTRODUCTION

In this era of information technology, billions of bits of data are created in every fraction of a second. With the advent of internet, creation and transfer of digital data (images, video and audio files) has grown many fold. Copying a digital data is very easy and too fast. Therefore it creates issues like protection of rights of the content and proving ownership. Digital watermarking is a technique and a tool to overcome the shortcomings of current copyright laws for digital data. The watermark remains intact to the cover work even if it is copied. In order to prove ownership or copyrights of data, watermark is extracted and tested. For counterfeiters, it is very difficult to remove or change watermark. The real owner can always have his data safe and secure.

Watermarking has its applications in image/video copyright protection. The properties of a watermarking algorithm depend upon the application it was designed for. The following are the basic properties of watermarking:

i) Imperceptibility – A watermark is called perceptible when its presence in the marked signal is noticeable, but non-intrusive and is called imperceptible when the cover signal and marked signal are indistinguishable with respect to an appropriate perceptual metric.

ii) Robustness – It means the watermark is able to survive any reasonable processing inflicted on the carrier and is called fragile when it fails to detect a slight modification.

iii) Security – It means the watermarked image should not give any information of the presence of the watermark with respect to un-authorized detection, or unsuspicious [1].

iv) Complexity- It describes the cost to detect and encode the watermark information. It gives idea to design complex watermarking procedure and algorithm. So that it can be integrated with different watermarks.

v) Capacity- It means the amount of information that can be stored in a data source.

Digital image watermarking algorithms can be classified into two main categories according to the embedding domain: spatial and transform domain schemes. The spatial domain watermarking methods are simpler and are less robust against various geometric and non geometric attacks [2]. The representative transform-domain techniques embed the watermark by modulating the magnitude of coefficients in a transform domain, such as DWT and SVD [3], [4]. Transform domain methods can yield more information embedding and more robustness against many common attacks. But the computational cost is higher than spatial-domain watermarking methods.

DWT is very suitable to identify areas in the cover image where as a watermark can be imperceptibly embedded due to its excellent spatio - frequency localization properties. One of the important mathematical properties of SVD is that slight variations of singular values do not affect the visual perception of the host image, which motivates the watermark embedding procedure to achieve good transparency and robustness [5].

The proposed watermarking scheme is based on DWT and SVD technique. Two watermark images are embedded in the LH and HL bands of the cover image after two level DWT decomposition. The embedding is done by modifying the singular values in LH and HL bands of the cover image with the singular values of the watermark images.

The paper is organized as follows. Section II discuss about DWT. Section III explains the SVD. Section IV describes the proposed system. Section V gives the simulation results and section VI projects the performance analysis. Finally section VI gives the conclusion.

II. DWT

The DWT divides an image into four parts namely a lower resolution approximation component (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The LL sub band is obtained after low-pass filtering both the rows and columns and contains a rough description of the image. The HH sub-band is high-pass filtered in both directions and have the high-frequency components along the diagonals. The HL and LH sub bands are the results of low-pass filtering on one direction and high-pass filtering in the other direction. After the image is processed by the wavelet transform, most of the information contained in the host image is concentrated into the LL image. LH sub band contains mostly the vertical detail information which corresponds to horizontal edges. HL band represents the horizontal detail information from the vertical edges. The process can be repeated to obtain multiple 'scale' wavelet decomposition [6]. Figure 1 shows the DWT decomposition.

DWT plays an important role in the image processing field. It has many special advantages over other conventional transforms such as Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT). The DFT and DCT are full frame transforms and hence any change in the transform coefficient affects the entire image. However, there are cases where the transformation is implemented using a block based approach [7] to alleviate this problem. Because of these reasons, the wavelet based watermarking techniques are getting more significance.

DWT is very useful to identify the areas in the host image where a watermark can be embedded effectively. This property allows the exploitation of the masking effect of the human visual system. When a DWT coefficient is modified, the region corresponding to that coefficient alone is modified. In general, most of the image energy is concentrated at the lower frequency sub-bands LL. Therefore embedding watermarks in LL sub bands may significantly degrade the image. Embedding in the low frequency sub-bands, however, significantly improves the robustness. Whereas, the high frequency sub-bands HH include the edges and textures of the image and the human eye is less sensitive to changes in such sub-bands. It allows the watermark to be embedded without being perceived by the human eye. So as to improve the robustness and imperceptibility, watermark embedding is done in the intermediate frequency bands HL and LH [8].

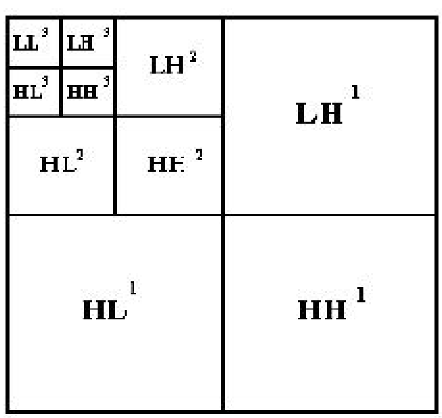


Figure 1. DWT decomposition.

III. SVD

Let A be a general real matrix of order m x n and its SVD is the factorization:

$$A = P * Q * R^T \quad (1)$$

Where P and R are orthogonal (unitary) matrices and Q = diag (F_1, F_2,...,F_r), where F_i, i = 1 to r is the singular values of the matrix A with r = min (m, n) and it satisfies:

$$F_1 \geq F_2 \geq \ldots \geq F_r \quad (2)$$

The first r columns of P and R are the left and right singular vectors of A respectively. There are many advantages to use SVD in digital image processing. Firstly, the SVD transformation can be applied to an image with arbitrary sizes. It can be a square or a rectangle. Secondly, singular values of the digital image are less affected if general image processing is performed. Lastly singular values contain intrinsic algebraic properties of an image. The singular values avoid following types of geometric distortions:

i) Transpose: The singular value of matrix A and its transpose A^T having same non-zero singular values.
ii) Flip: A row- flipped A_{rf} and column-flipped A_{cf} having same non-zero singular values.
iii) Rotation: A and A_r (A rotated by an arbitrary degree) having same non-zero singular values.
iv) Scaling: B and C are row and column- scaled version of A by repeating every row and column, L_1 and L_2 times respectively. For each nonzero singular value λ of A, C has L_2λ. If D is row-scaled by L_1 times and column-scaled by L_2 times than for each non-zero singular value λ of A, D has $L_1 L_2 \lambda$.
v) Translation: The resultant matrix A_e is expanded version of matrix A by adding rows and columns of black pixels and it have the same non-zero singular values as A [9].

IV. PROPOSED SYSTEM

The proposed system is based on DWT SVD technique. The host image and the watermark images are decomposed by DWT using Haar wavelet. Two level decomposition was applied on the host image and single level decomposition on the watermark images. The watermark images are embedded on the HL and LH bands of the host image by modifying the singular values of the host image. Figure 2 shows the proposed method.

A. *Algorithm – Embedding watermark*

i) Apply 2-level Haar wavelet transform on the host image.

ii) Perform singular value decomposition in the HL and LH band of host image.

$$H_1 = P_{H_1} * Q_{H_1} * R_{H_1}^T \quad (3)$$

$$H_2 = P_{H_2} * Q_{H_2} * R_{H_2}^T \quad (4)$$

iii) Apply first level Haar wavelet transform on the watermark images.

iv) Perform singular value decomposition on HL band of watermark image 1

$$W_1 = P_{W_1} * Q_{W_1} * R_{W_1}^T \quad (5)$$

v) Perform singular value decomposition on LH band of watermark image 2.

$$W_2 = P_{W_2} * Q_{W_2} * R_{W_2}^T \quad (6)$$

vi) Modify the singular value of the host image with the singular value of the watermark images.

$$Q_{WM} = Q_H + \alpha Q_W \quad (7)$$

vii) Obtain the modified image.

$$I = P_H * Q_{WM} * R_H^T \quad (8)$$

viii) Apply inverse DWT to obtained the watermarked image.

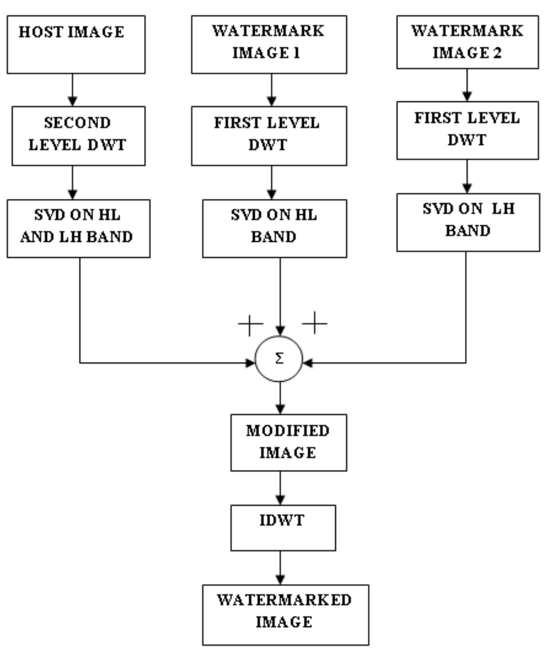


Figure 2. Proposed system.

B. Algorithm – Extracting the watermark

i) Perform 2-level wavelet transform on the watermarked image.

ii) Perform SVD on the HL and LH bands of the watermarked image.

$$I_{WM} = P_{WM} * Q_{WM} * R_{WM}^T \quad (9)$$

iii) The singular values of secondary watermark can be extracted as

$$Q'_W = (Q_{WM} - Q_H)/\alpha \quad (10)$$

iv) The watermark image can be obtained as

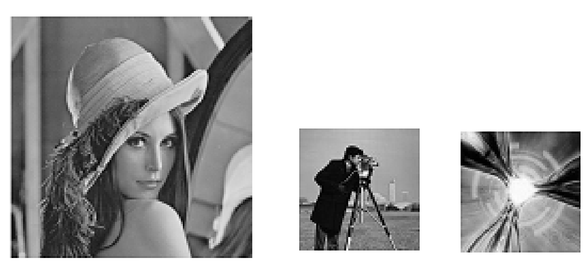
$$W' = P_W * Q'_W * R_W^T \quad (11)$$

V. SIMULATION RESULTS

The proposed algorithm is demonstrated using MATLAB. 8-bit gray scale Lena image of size 256 x 256 is selected as host image. The gray level images Cameraman of size 128x128 and Light of size 128x128 are used as watermark image 1 and the watermark image 2, respectively. Figure 3 shows the host image and watermark images. Figure 4 shows the watermarked image and extracted watermarks without noise attacks. It can be seen that the proposed method preserves the perceptual quality of the watermarked mage.

(a) (b) (c)

Figure 3. (a) Host image. (b) Watermark image 1. (c) Watermark image 2



(d) (e) (f)

Figure 4. (d) Watermarked image (PSNR=69.2029). (e) Extracted watermark image 1. (f) Extracted watermark image 2.

VI. PERFORMANCE ANALYSIS

To investigate the robustness of the algorithm, the watermarked image is subjected to various types of attacks such as Gaussian noise, salt and pepper noise, speckle noise and Gaussian blur attacks. Additive Gaussian noising is a process that adds a noise signal to an image in order to deliberately corrupt the image, hence reducing its visual quality. Gaussian noise attack is similar to a high pass filter. The process increases the variation in pixel values to the extent that, local edges start appearing in the image. Salt and pepper noise is also called impulse noise and it can be caused by sudden and sharp disturbances in the image signal. It appears as randomly occurring white and black pixels over the image. Salt and pepper noise attack is also essentially a high pass filter function. Gaussian blurring is a process that averages the value of pixels over an area using weighing coefficients derived from a Gaussian function. It is often used to reduce noise or to reduce pixilation in an image. Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and Synthetic Aperture Radar (SAR) images. Speckle noise in SAR is generally more serious causing difficulties for image interpolation. Figure 5 shows the attacked watermarked images.

Figure 5. Attacked watermarked after (a) Speckle noise. (b) Salt & Pepper noise. (c) Gaussian noise. (d) Gaussian blur.

As a quantitative measure of the degradation effect caused by the attacks PSNR is used. The PSNR between the original I (t) and the attacked watermarked J (t) signals is calculated using (12) and (13). High PSNR values indicate lower degradation, hence indicating that the watermarking technique is more robust to various attacks. Table I shows the RMSE and PSNR values watermarked image from different attacks.

$$\text{PSNR}=20\log_{10}\left(\frac{255}{\text{RMSE}}\right) \tag{12}$$

RMSE, the square root of mean square error is defined as:

$$\text{RMSE}=\sqrt{\frac{1}{T}\sum_t^T (I(t)-J(t))^2} \tag{13}$$

TABLE I
RMSE &PSNR VALUES OF WATERMARKED IMAGE FROM DIFFERENT ATTACKS

Attacks	RMSE	PSNR (dB)
Gaussian blur	0.0756	59.3430
Gaussian noise	5.4824	40.7411
Salt & pepper noise	0.3529	52.6537
Speckle noise	2.8370	43.6022

For comparing the similarities between the original and extracted watermarks, the correlation coefficient was employed. The normalized coefficient (NC) gives a measure of the robustness of watermarking and its peak value is 1.

$$\text{NC}=\frac{\sum_i\sum_j W(i,j).W'(i,j)}{\sqrt{\sum_i\sum_j W(i,j)}\sqrt{\sum_i\sum_j W'(i,j)}} \tag{14}$$

Where w and w' represents the original and extracted watermark respectively [10]. Table II shows the correlation coefficient values of extracted watermarks from different attacks. It can be observed that the proposed method is robust to various attacks. Figure 6 shows the extracted watermarks after different attacks.

TABLE II
CORRELATION COEFFICIENT VALUES OF EXTRACTED WATERMARKS FROM DIFFERENT ATTACKS

Attacks	Watermark image1	Watermark image2
Gaussian blur	0.9869	0.9893
Gaussian noise	0.7257	0.7371
Salt & pepper noise	0.8961	0.9191
Speckle noise	0.9151	0.9347

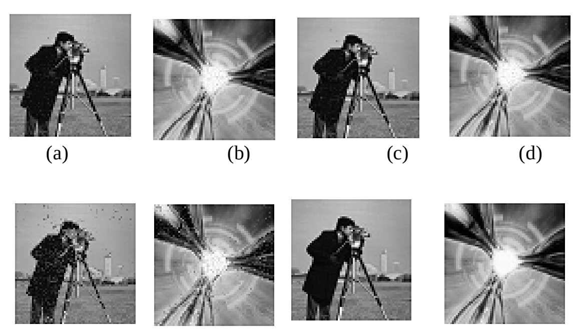


Figure 6. Extracted watermarks (a) watermark image 1 after speckle noise .(b) watermark image 2 after speckle noise. (c) watermark image 1 after salt& pepper noise. (d) watermark image 2 after salt &pepper noise .(e) watermark image 1 after Gaussian noise (f) watermark image 2 after Gaussian noise. (g) watermark image 1 after Gaussian blur .(h) Watermark image 2 after Gaussian blur.

CONCLUSIONS

This paper deals with a new DWT SVD watermarking technique in which two watermark images are embedded in the HL and LH bands of the host image after two level DWT decomposition of the host image using Haar wavelet by modifying the singular values of the host image with that of watermark images. The performance was evaluated using RMSE, PSNR and correlation coefficient. Simulation results show that this method is robust against various types of attacks.

REFERENCES

[1] P. Tejaswini, K. Manjunath, A. Mahendran, " Digital Watermarking Using DWT-SVD," International Journal of Scientific & Engineering Research Volume 3, Issue 8, Aug. 2012.

[2] R. Liu and T. Tan, "An SVD-based watermarking scheme for protecting rightful ownership," IEEE Trans. Multimedia, vol. 4, no. 1, pp. 121–128, Mar. 2002.

[3] A. Nikolaidis and I. Pitas, "Asymptotically optimal detection for additive watermarking in the DCT and DWT domains," IEEE Trans. Image Process, vol. 12, no. 5, pp. 563–571, May 2003.

[4] J. R. Hernandez, M. Amado, F. Perez-Gonzalez, "DCT-domain watermarking techniques for still images: detector performance analysis and a new structure," Image Processing, IEEE Transactions on 9, pp. 55–68, Jan 2000.

[5] Chih-Chin Lai, C.-C. Tsai, "Digital image watermarking using discrete wavelet transform and singular value decomposition," IEEE Transactions on Instrumentation and Measurement, vol. 59, No.11, pp. 3060-3063, Nov. 2010.

[6] L. Ying-Hua, Q. Jing, K. Jun, L. Si-Hui, "A robust digital watermarking scheme based on optimal coefficients selector about sub images, Wavelet Analysis and Pattern Recognition," 2007. ICWAPR '07. International Conference on, 2–4 Nov. 2007, pp. 1865–1869.

[7] B. Jagadeesh, S. S. Kumar, K. R. Rajeswari, " Image watermarking scheme using singular value decomposition, quantization and genetic algorithm, Signal Acquisition and Processing", 2010. ICSAP '10. International Conference on, 9–10 , pp. 120–124, Feb. 2010.

[8] Chunlin Song , Sud Sudirman, Madjid Merabti, "A robust region-adaptive dual image watermarking technique," Elsevier Journal of Visual communication and image reconstruction, pp. 549–568, Feb. 2012.

[9] R.Dhanalakshmi, K.Thaiyalnayaki, "Dual Watermarking Scheme with Encryption," International Journal of Computer Science and Information Security, Vol. 7, No. 1,pp.248-253,Jan. 2010.

[10] Sanjana Sinha, Prajnat Bardhan, Swarnali Pramanick, Ankul Jagatramka, Dipak K. Kole, Aruna Chakraborty, "Digital Video Watermarking using Discrete Wavelet Transform and Principal Component Analysis," International Journal of Wisdom Based Computing, Vol. 1 (2), pp. 7-12, Aug. 2011.