A Robust Invisible Digital Image Watermarking using DWT, DCT and SVD

Sonam Chauhan, Sachin Chaudhary
Department of Information Technology, DIT University,
Dehradun,Uttarakhand,India.
Department of Information Technology, DIT University,
Dehradun,Uttarakhand,India.

ABSTRACT

In today's growing world of digital technology, access to the multimedia content is very easy and for some sensitive applications such as medical imaging, military system, legal problems, it is very essential to not only reinstate the original media without any loss of information but also to increase content's security. Reversible data hiding is an approach to extract the information embedded covertly as well as the host image. In this paper, we have proposed a novel hybrid invisible watermarking scheme based on DWT, DCT and SVD. In this scheme, we have provided double layer of security by utilizing the multi-resolution property of wavelet and strong features of DCT and SVD. In the proposed scheme, watermark is embedded into the singular values of all high frequency sub-bands obtained by wavelet decomposition of the original image and at the time of extraction, watermark bits are used along with singular vectors to obtain the original image.

Indexing terms/Keywords

Invisible watermarking, DWT,DCT,SVD..

Academic Discipline And Sub-Disciplines

Cryptography,Steganography

Council for Innovative Research

1.INTRODUCTION

1.1 General

In the past few years the digitization of multimedia has increased dramatically. Media can be shared between people around the world, within minutes, by use of computer networks such as the World Wide Web. Also digital media are easily and quickly edited by anyone with a computer. In such a time as this, copyright protection and copy control becomes very difficult.

In an attempt to create a copyright protection system researchers have turned to the field of digital watermarking. In the past few years, research into digital watermarking has increased dramatically.

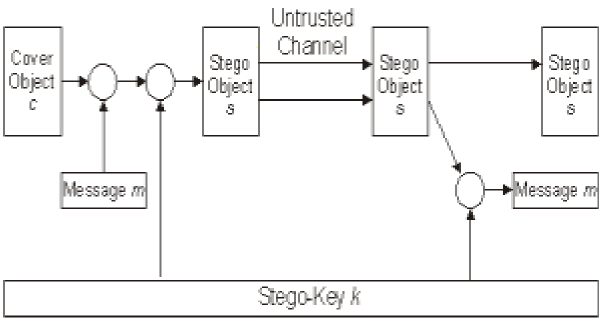


Fig. 1 Illustration of a Steganographic System

1.2 Criteria for a Good Watermark

Though watermarks belong to different categories, some of the general characteristics that watermarks must possess are the following:

1.The watermark must be strongly bound to the image and any changes to the watermark must be apparent in the image.

2 .Watermark must also be able to withstand changes made to the image. Such changes include modifications and enhancements of images such as size modifications, cropping, lossy compression, to name a few.

3.The watermark must not undermine the visual appeal of the image by its presence (especially for invisible watermarks).

4.Watermark must be indelible and must be able to survive linear or non-linear operations on the image.

2. Image Decomposition

2.1 Wavelet transforms

Wavelet transform is a powerful tool for signal and image processing tasks because of multi-resolution analysis, sub-banding and localized in frequency and time domain.

In Two-dimensional DWT, the signals are transformed into low frequency component (LL) and high frequency component (LH; HL; HH). Further decomposition can be done as per requirement. The **wavelet packet** method provides richer range of possible information for image and signal analysis. Wavelet packet transform decomposes the images into low & high frequencies. The further decomposition of low and high frequencies is helpful to obtain detail characteristics of images. In wavelet packet analysis, both the detail and approximation part can be split. However in DWT only approximation part can split.

In various papers, a full wavelet packet tree is used where decomposition level is based on a cost function. A cost value is generated for each sub band in top down approach manner. Various types of cost function are used such as Shannon entropy; wiener based cost function; and etc. here, Cost function for each sub band s is chosen as "log energy (LE)" and calculated as:

$$LE = \sum_{i} \log{(s_i)^2}$$

2.2 Discrete Cosine Transform (DCT)

A transformation function which transforms image from spatial domain to frequency domain which makes the analysis of a signal simple. DCT Watermarking is done by using direct application of transform to entire image or block wise. Two dimensional DCT is used in image compression, where vertical and horizontal dimensions are considered. Formulae for calculating DCT is given by Eq.(1) and inverse DCT is given by Eq.(2). An image is subdivided into 8x8 block of samples. Each of these 8x8 blocks of samples of the original image is mapped to the frequency domain. It is represented as a composition of DCT basic functions with appropriately chosen 64 coefficients, representing different horizontal and vertical intensities.

$$y(u,v) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\alpha_m\alpha_n \sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\{x(m,n) * \cos(2m+1)u\Pi 2M \cos(2n+1)u\Pi 2N\}$$

(1)

Where

$$\alpha_u = \begin{cases} \frac{1}{\sqrt{2}} & u = 0 \\ 1 & u = 1,2, \dots M-1 \end{cases}$$

$$\alpha_v = \begin{cases} \frac{1}{\sqrt{2}} & v = 0 \\ 1 & v = 1,2, \dots N-1 \end{cases}$$

The image is reconstructed by applying inverse DCT operation according to Eq(.2):

$$x(m,n) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}\{\alpha_m \alpha_n y(u,v) * \cos\frac{(2m+1)u\Pi}{2M}\cos\frac{(2n+1)u\Pi}{2N}\}$$
(2)

2.3 Singular Value Decomposition (SVD)

The Singular Value Decomposition is one of the most useful tools of linear algebra with several applications to multimedia. Applications including Image compression,Watermarking and other Signal Processing. Given a real matrix, A (m,n); 1≤ m ≤M, 1≤ n ≤ N, it can be decomposed into a product of three matrices given by Eq(3):

A = USVT (3)

where U and V are orthogonal matrices, U TU = I, V TV = I, and S = diag (λ1, λ2, ….. λr). The diagonal entries of S are called the singular values of A, the columns of U are called the left singular vectors of A, and the columns of V are called the right singular vectors of A. This decomposition is known as the Singular Value Decomposition (SVD) of A, and can be written as shown in Eq.4

A = λ1U1V1 T + λ2U2V2 T +…….+ λrUrVr (4) where r is the rank of matrix A. It is important to note that each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image layer. An important property of SVD based watermarking is that the largest of the modified singular values change very little for most types of attacks like transpose, flip, rotation, scaling and translation.

3.Proposed Technique

The process of separating the image into bands using the DWT is well-defined. In two-dimensional DWT, each level of decomposition produces four bands of data denoted by LL, HL, LH, and HH. The LL sub-band can further be decomposed to obtain another level of decomposition. In two-dimensional DCT, we apply the transformation to the whole image but need to map the frequency coefficients from the lowest to the highest in a zigzag order to 4 quadrants in order to apply SVD to each block. All the quadrants will have the same number of DCT coefficients. To differentiate these blocks from the DWT bands, we will label them B1, B2, B3, B4. This process is depicted in the following figure:

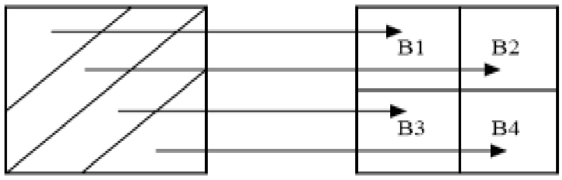


Fig. 2 Mapping of DCT coefficients into 4 blocks

In pure DCT-based watermarking, the DCT coefficients are modified to embed the watermark data. Because of the conflict between robustness and transparency, the modification is usually made in middle frequencies, avoiding the lowest and highest bands. Every real matrix *A* can be decomposed into a product of 3 matrices $A = U\Sigma V^T$, where *U* and *V* are orthogonal matrices, $U^TU = I$, $V^TV = I$, and Σ = diag ($\lambda 1$, $\lambda 2$, ...). The diagonal entries of Σ are called the singular values of *A*, the columns of *U* are called the left singular vectors of *A*, and the columns of *V* are called the right singular vectors of *A*. This decomposition is known as the **Singular Value Decomposition (SVD)**of **A**, and can be written as

$$A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 2 + \dots\dots\dots + \lambda_r U_r V_r^T,$$

Where *r* is the rank of matrix *A*. It is important to note that each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image.

In SVD-based watermarking, several approaches are possible. A common approach is to apply SVD to the whole cover image, and modify all the singular values to embed the watermark data. An important property of SVD-based watermarking is that the largest of the modified singular values change very little for most types of attacks. We will combine DCT and SVD to develop a new hybrid non-blind image watermarking scheme that is resistant to a variety of attacks. The proposed scheme is given by the following algorithm. Assume the size of visual watermark is *nxn*, and the size of the cover image is 2*n*x2*n*.

3.1Watermark Embedding

1. Apply WPT and DCT to the whole cover image A.

2 .Using the zigzag sequence, map the DCT coefficients into 4 quadrants:B1, B2, B3, B4.

3. Apply SVD to each quadrant:

$$A^k = U_A^k \Sigma_A^k V_A^{kT},$$

k=1,2,3,4 , where k denotes B1, B2, B3, B4 quadrants.

4. Apply DCT to the whole visual watermark W.

5.Apply SVD to the DCT-transformed visual watermark W.

$$W = U_W \Sigma_W V_W^T$$

6. Modify the singular values in each quadrant B_k, k=1,2,3,4, with the singular values of the DCT-transformed visual watermark:

$$\lambda_i^{*k} = \lambda_i^k + \alpha_k \lambda_{wi,} \quad i = 1, \dots\dots, n$$
$$where\ \lambda_i^k,$$

$$i = 1, \dots\dots, n\ are the\ singular\ values\ of\ \Sigma_A^k,$$

$$and\ \lambda_{wi}\,,$$

$$i = 1, \dots\dots, n\ are\ the\ singular\ values\ of\ \Sigma_W.$$

6 .Obtain the 4 sets of modified DCT coefficients:

$$A^{*k} = U_A^k \Sigma_A^{*k} V_A^{kT}, \quad k = 1,2,3,4$$

7 .Map the modified DCT coefficients back to their original positions.

8. Apply the inverse DCT to produce the watermark cover image.

3.2 Watermark Extraction

1. Apply WPT and DCT to the whole watermarked (and possibly attacked) cover image A^*.

2 .Using the zigzag sequence, map the DCT coefficients into 4 quadrants:

B1, B2, B3, B4.

3.Apply SVD to each quadrant:

$A^{*k} = U_A^k \Sigma_A^{*k} V_A^{kT}$,

k = 1,2,3,4 where k denotes

B1, B2, B3, B4 quadrants.

4. Extract the singular values from each quadrant B_k, k=1,2,3,4:

$$\lambda_{wi}^k = \frac{\lambda_i^{*k} - \lambda_i^k}{\alpha_k}, \qquad i = 1, \dots\dots, n$$

5. Construct the DCT coefficients of four visual watermarks using the singular vectors:

$$W^k = U_W^k \Sigma_W^k V_W^{kT}, \qquad k = 1,2,3,4$$

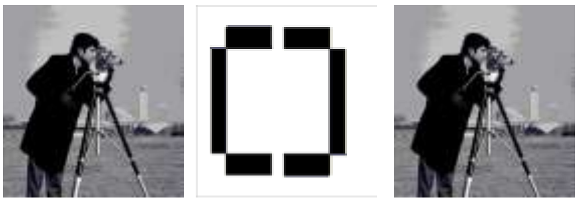
6.Apply the inverse DCT to construct the four visual watermarks.

4.Results and analysis

The experimental results are tested on various images of size 256×256. Over the input images, the watermark is embedded based on wavelet transform using DCT and SVD as discussed in proposed methodology. The resultant watermarked image of proposed scheme is shown in Fig.3(c). Fig.4(c) is showing the results of watermark extraction.The visual quality of results is good in comparision of existing methods. To measure the quality of proposed scheme in terms of MSE and PSNR, the results are compared with existing schemes,as shown in Table 1.

Since the magnitudes of DWT coefficients are larger in the lowest band at each level of decomposition, It is possible to use a larger scaling factor for watermark embedding. For the other 3 bands, the DWT coefficients are smaller, allowing a smaller scaling factor to be used. The resulting watermarked image does not have any degradation leading to a loss in its commercial value. In the below experiments, we measured the visual quality of watermarked and attacked images using the Signal To-Noise Ratio (SNR), SNR measures are estimates of the quality of the reconstructed image compared with an original image. The fundamental idea is to compute the value which reflects the quality of the reconstructed image. Reconstructed image with higher metric are judged as having better quality.

The visual quality of extracted visual watermarks is measured by the Similarity Factor (SF). The DWT was performed using Matlab with the wavelet filter. The chosen attacks were JPEG compression (with 3 quality factors), also we measured a compression ratio (CR) it defined by compression Ratio=image bytes/compressed bytes.



(a) (b) (c)

Fig..3 Results of watermark embedding (a) Input cameramen image (b) Watermark image and (c) Invisible watermarked image

(a) (b) (c)

Fig.4 Results of watermark extraction(a) Input cameramen image (b) Waterm

Table 1: Comparison of Lee's method, DWT+SVD method and the proposed scheme

Attack Type	Similarity (W,W^*)			
	Lee's method		DWT+SVD	Proposed method
No attack	0.727		0.9811	0.9912
Median filtering	2X2	0.611	0.6745	0.8773
	3X3	0.629	0.8732	0.9672
	4X4	0.609	0.8323	0.8473
Gaussian filtering	([3,3],0.5)	0.671	0.9237	0.9897
Lossy JPEG compression (Quality factor)	80	0.660	0.9238	0.9648
	70	0.623	0.9127	0.9537
	60	0.579	0.9312	0.9361
	50	0.532	0.9012	0.9100
	40	0.477	0.8712	0.8776
Centered cropping	5%	0.703	0.9614	0.9633
	25%	0.621	0.7432	0.7985
	50%	0.446	0.5124	0.5870
Rescaling (Estimated scaling ratio)	1.5X	0.524	0.9532	0.9984
	1.3X	0.594	0.9344	0.9714
	1.1X	0.606	0.9234	0.9221
	0.9X	0.605	0.9211	0.9807
	0.8X	0.539	0.9431	0.9443
	0.7X	0.472	0.9342	0.9058
Rotation with cropping (Estimated rotation angle)	0.25°	0.682	0.8341	0.8950
	0.5°	0.673	0.8231	0.8898
	0.75°	0.662	0.7231	0.9615
	1°	0.643	0.6231	0.8536
	2°	0.550	0.7212	0.9322
	5°	0.641	0.4334	0.9283
	10°	0.600	0.4341	0.8750
	15°	0.538	0.4345	0.8347
	30°	0.514	0.4782	0.8079
	45°	0.550	0.4873	0.8557

5. Conclusion

In this paper, wavelet packet transform is used for embedding and extraction of watermark in depth of the images. The singular values of approximation image formed by DC values of blocks of the cover image are changed with the singular values of watermark image. Experimental results show that the proposed watermarking technique yields strong robustness to the geometrical and image processing attacks and imperceptibility of the watermarked image is also promising. The watermarks can be extracted from the distorted image after most of the common image processing attack with high normalized correlation values.

References

[1].Edin Muharemagic and Borko Furht, "Survey Of Watermarking Techniques And Applications", Department of Computer Science and Engineering, Florida Atlantic University.

[2]. Andreja Samˇcovi´c, J´an Tur´an, "ATTACKS OnDIGITALWAVELET IMAGEWATERMARKS", Journal of ELECTRICAL ENGINEERING

[3].Peining Taoa and Ahmet M. Eskicioglub, "A robust multiple watermarking scheme in the Discrete Wavelet Transform domain ", The Graduate Center, The City University of New York.

[4]. Baisa L. Gunjal, "AN OVERVIEW OF TRANSFORM DOMAIN ROBUST DIGITAL IMAGE WATERMARKING ALGORITHMS", Department of Computer Engineering, Amrutvahini College of Engineering.

[5]. R. Gonzales, R. Woods "Digital Image Processing", Addison-Wesley Publishing Company.

[6]. Min Wu Bede Liu, "WATERMARKING FOR IMAGE AUTHENTICATION", Department of Electrical Engineering, Princeton University, Princeton.

[7] S.D. Lin, S.-C. Shie, J.Y. Guo, Improving the robustness of DCT-based imagewatermarking against JPEG compression, Comput. Stand. Interfaces 32 (2010)54–60.

[8] J.C. Patra, J.E. Phua, C. Bornand, A novel DCT domain CRT-based watermarkingscheme for image authentication surviving JPEG compression, Digit. SignalProcess. 20 (2010) 1597–1611.

[9] T.-H. Lan, A.H. Tewfik, A novel high-capacity data-embedding system, IEEETrans. Image Process. 15 (8) (2006) 2431–2440.

[10] J.-M. Guo, C.-H. Chang, Prediction-based watermarking schemes usingahead/post AC prediction, Signal Process. 90 (2010) 2552–2566.

[11] A. Phadikar, S.P. Maity, B. Verma, Region based QIM digital watermarkingscheme for image database in DCT domain, Comput. Electr. Eng. 37 (2011)339–355.

[12] J.-M. Shieh, D.-C. Lou, M.-C. Chang, A semi-blind digital watermarking schemebased on singular value decomposition, Comput. Stand. Interfaces 28 (4) (2006)428–440.

[13] A.A. Mohammad, A. Alhaj, S. Shaltaf, An improved SVD-based watermarkingscheme for protecting rightful ownership, Signal Process. 88 (9) (2008)2158–2180.

[14] W. Lu, H. Lu, F.-L. Chung, Feature based robust watermarking using imagenormalization, Comput. Electr. Eng. 36 (2010) 2–18.

[15] V. Solachidis, I. Pitas, Optimal detection for multiplicative watermarks embeddedin DFT domain, in: Proceedings of IEEE International conference on ImageProcessing 2003, Barcelona, Spain, 2003, pp. 723–726.

[16] D. Kundur, D. Hatzinakos, Toward robust logo watermarking using multiresolutionimage fusion principles, IEEE Trans. Multimedia 6 (2004) 185–198.

[17] M. Ouhsain, A.B. Hamza, Image watermarking scheme using nonnegativematrix factorization and wavelet transform, Expert Syst. Appl. 36 (2) (2009)2123–2129.

[18] G. Bhatnagar, R. Balasubramanian, A new robust reference watermarkingscheme based on DWT-SVD, Comput. Stand. Interfaces 31 (5) (2009)1002–1013.

[19] A. Nikolaidis, I. Pitas, Asymptotically optimal detection for additive watermarkingin the DCT and DWT domains, IEEE Trans. Image Process. 12 (5) (2003)563–571.

[20] E.E. Abdallah, A.B. Hamza, P. Bhattacharya, Improved image watermarkingscheme using fast Hadamard and discrete wavelet transforms, J. Electron. Imaging16 (3) (2007) 0330201–0330209.

[21] S. Alexander, D. Scott, M.E. Ahmet, Robust DCT-SVD domain image watermarkingfor copyright protection: embedding data in all frequencies, in: Proc.of the 13th European Signal Processing Conference (EUSIPCO2005), 2005, pp.4–8.

[22] Renjini L, Jyothi R L"Wavelet Based Image Analysis:A Comprehensive Survey". International Journal of Computer Trends and Technology (IJCTT) V21(3):134-140

[23] Gurpreet kaur , Rajdavinder Singh."Image Enhancement and Its Techniques- A Review". International Journal of Computer Trends and Technology (IJCTT) V12(3):148-151, June 2014. ISSN:2231-2803.

[24] A.Devi, Dr.A.Marimuthu."Image Processing Techniques in Face Recognition"***International Journal of Computer Trends and Technology (IJCTT)***,V4(2):54-62 Issue 2013 .ISSN 2231-2803