ICSP2012 Proceedings

Highly Robust Image Watermarking in Contourlet Domain Using Singular Value Decomposition

Hamidreza Sadreazami*, Marzieh Amini**
*Electrical Engineering Department, Shahid Beheshti University, hm.sadreazami@mail.sbu.ac.ir
** Electrical Engineering Department, University of Semnan, m_amini@semnan.ac.ir

Abstract— *In this paper, we propose a new method of image watermarking by using contourlet transform along with singular value decomposition. Contourlet transform is a new two-dimensional extension of the wavelet transform using multi-scale and directional filter banks. For security aspect of the watermarking algorithm and to improve imperceptibility of the algorithm, watermark bits are permuted by an interleaver. In embedding part, contourlet transform is applied to host image and appropriate direction is selected by considering intensity variance of all directions. Coefficients are modified by combining singular values of selected direction with singular values of watermark image. Experimental results show no visible difference between host and watermarked images. The proposed watermarking method is also robust to various attacks such as JPEG compression, rotation, histogram modification, Gaussian and median filtering and gamma correction.*

Keywords: Contourlet transform, Digital image watermarking, Singular value decomposition.

I. INTRODUCTION

In recent years, due to development of the Internet, data authentication has attracted great research interests. Digital watermarking, known as a possible solution for this matter, is a way of embedding a key into the original data in order to increase security and copyright protection.

Watermarking can be divided into two categories: space domain and transform domain. In general, transform domain watermarking is more complex but more robust than space domain watermarking [1]. Discrete wavelet transform which has good local analysis performance both in time and frequency domain, and becomes one of the most prevalent transform domains to embed watermarks [2-4].

However, normal wavelets have poor directional selectivity, regarding impulse responses of the filters in each subband. Also, small shifts in input signal cause big changes in the energy distribution of the wavelet coefficients, due to lack of shift invariance characteristic.

Contourlet transform (CT), proposed in 2002 [5], provides a flexible multiresolution, local and directional image expansion. Compared with wavelet transform, it is not limited to three directions; it makes better use of the image geometric characteristics because of its double filter bank structure.

978-1-4673-2197-6/12/$31.00 ©2012 IEEE

Nowadays, many experts have focused on the watermarking technique in CT domain [6-10]. However, their schemes seem to do not possess good visual quality and robustness against many local and global attacks.

This paper presents a new watermarking method in contourlet transform domain. The embedding strategy is commenced with applying CT to the host image. In order to insert the watermark, the most significant direction based on its variance intensity is selected. Then, we apply singular value decomposition (SVD) to both selected subband and watermark image. The singular values of watermarked image are modified by combining the singular values of selected subband with singular values of watermark image. As a result, we achieve high robustness and perceptual transparency.

The rest of the paper is organized as follows: sections II and III provide a quick review on contoutlet transform and singular value decomposition, respectively. In section IV, proposed watermarking method is explained. Experimental results are presented in section V. Section VI concludes the paper.

II. CONTOURLET TRANSFORM

The contourlet transform, introduced by Do and Vetterli [5], is a new image decomposition scheme, which provides a flexible multiresolution representation for 2-D signals. The CT is constructed by two filter banks; a Laplacian Pyramid (LP) followed by a Directional Filter Bank (DFB). In the contourlet transform, LP decomposes an image into a low frequency subband and a high frequency subband, whereas a DFB decomposes every bandpass image into many directions.

Finally, the image is represented as a set of directional subbands at multiple scales. The schematic structure of contourlet transform and its frequency partition are illustrated in Fig. 1 and Fig. 2, respectively.

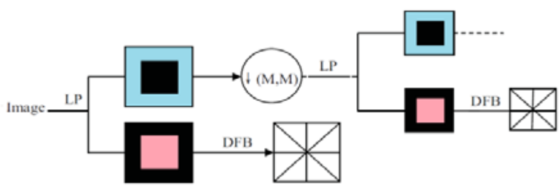


Figure 1. Diagram of contourlet transform.

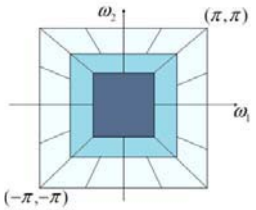


Figure 2. Frequency partitions in contourlet transform.

III. SINGULAR VALUE DECOMPOSITION

Singular value decomposition is one of the most efficient linear algebra tools, widely used in digital image watermarking [11, 12]. Through this technique, every real matrix A can be decomposed into a product of three matrices as $A = U\,S\,V^T$, where U and V are orthogonal matrices i.e. $U^T U = I$, $V^T V = I$ and S is a diagonal matrix as $S = diag(\lambda_1, \lambda_2, ...)$. Diagonal entries of S are called the singular values of A. The columns of U and V are called the left and right singular vectors of A, respectively. This decomposition is known as the SVD of A, and can be written as in (1), where r is the rank of matrix A.

$$A = \lambda_1 U_1 V_1^T + \lambda_2 U_2 V_2^T + ... + \lambda_r U_r V_r^T \qquad (1)$$

The singular value of images is noticeably stable which means that the singular value of an image changes little when a small disturbance is imposed. Also, each singular value specifies the luminance of an image layer while the corresponding pair of singular vectors specifies the geometry of the image layer. So, due to these properties of singular values, singular value decomposition is very suitable for watermarking schemes.

IV. PROPOSED WATERMARKING PROCEDURE

We assume a grayscale image I of size $N \times N$ as the host image and binary image W of size $M \times M$ as the watermark image.

A. Embedding Procedure

The embedding process includes following steps :

- Permuting the watermark bits randomly using an interleaver with a secret seed in order to disperse the spatial relationship and to increase the invisibility, shown in Fig. 3.

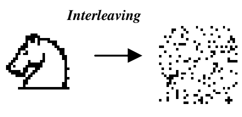


Figure 3. Watermark logo before and after interleaving.

- Performing four level contourlet transform to the host image, getting the approximate subband and three detail subbands in the last level, shown in Fig. 4.

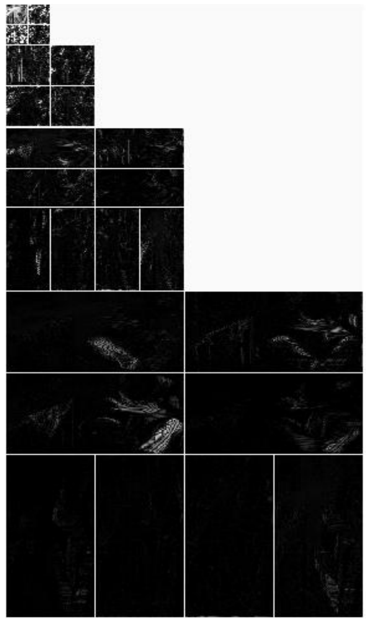


Figure 4. Contourlet transform decomposition of Barbara image.

- To select the most suitable subband, the intensity variance of each detail subband is calculated and subband A_S with the midst value is selected [12].
- Applying SVD to the selected directional subband A_S.

$$A_S = U_S S_S V_S^T \qquad (2)$$

- Applying SVD to watermark image.

$$W = U_W S_W V_W^T \qquad (3)$$

- Combining singular values of selected directional subband with the singular values of the watermark using the following equation,

$$S_S^W = S_S + a\,S_W \qquad (4)$$

where a is the embedding intensity factor.

- The modified directional subband is obtained as in (5),

$$A_S^W = U_S S_S^W V_S^T \qquad (5)$$

- Performing inverse contourlet transform to obtain the watermarked image.

B. Extraction Procedure

As our proposed watermarking method is a non-blind watermarking, the host image is required in watermarking extraction. If I^* is the watermarked image after facing various types of attacks, the detection process is as follows :

- Performing contourlet transform to the watermarked image I^*.

- Considering appropriate subband in the same way as in embedding, the singular values of the selected directional subband is computed as

$$A_S^* = U_S^* S_S^* V_S^{*T} \tag{6}$$

- Obtaining the singular values of the watermark image in (7),

$$S_{w-extracted} = \frac{(S_s^* - S_s)}{a} \tag{7}$$

- Applying inverse SVD.
- Watermark logo is recovered after deinterleaving with its correspond secret seed.

V. EXPERIMENTAL RESULT

In order to demonstrate the performance of the proposed watermarking method, we conducted some experiments on standard 512×512 Barbara grayscale image and a binary watermark image with size of 32×32. The Barbara image is transformed by CT using "pkva" pyramid and directional filters to obtain 4-level decomposition. Then, the watermark image is embedded into the host image by discussed method. The peak signal to noise ratio (PSNR) is calculated to show visual fidelity of the algorithm. Furthermore, the normalized correlation (NC) is obtained to prove high robustness of the proposed watermarking method.

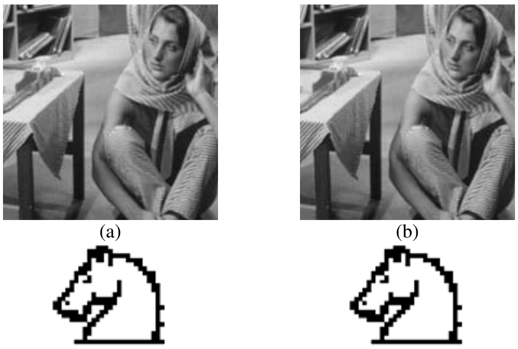
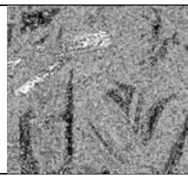
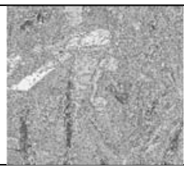
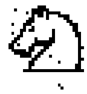
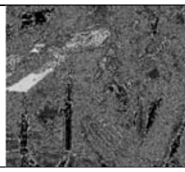
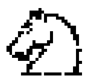
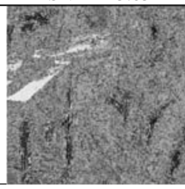
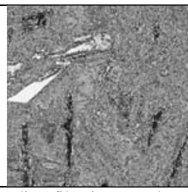
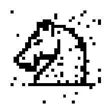


Figure 5 . (a) Original host image of 512×512, (b) Watermarked image, PSNR = 75.78, (c) Watermark logo of 32×32 , (d) Extracted watermark, NC = 1

TABLE I. Extracted watermark with corresponding NC and PSNR values of watermarked Barbara image against various kinds of attacks.

	
rotation 5°	Extracted Watermark
PSNR = 13.63	NC = 0.998
	
rotation 10°	Extracted Watermark
PSNR = 12.03	NC = 0.970
	
histogram modification	Extracted Watermark
PSNR = 21.03	NC = 1
	
gamma correction $\gamma = 0.5$	Extracted Watermark
PSNR = 13.82	NC = 0.994
	
gamma correction $\gamma = 2$	Extracted Watermark
PSNR = 13.63	NC = 0.990
	
Gaussian filtering mask 7×7	Extracted Watermark
PSNR = 35.70	NC = 1
	
median filtering mask 7×7	Extracted Watermark
PSNR = 23.33	NC = 0.967

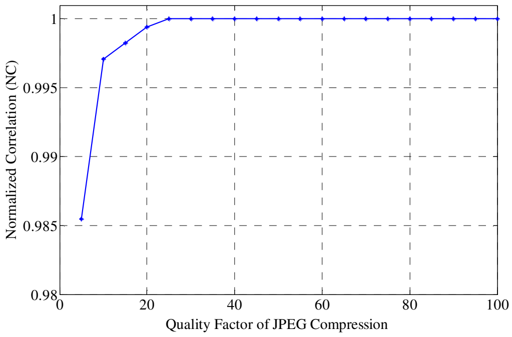


Figure. 6: NC corresponding to the JPEG compression attack with different quality factors.

It can be seen from Fig. 5 that the visual effect of watermarking on original image is imperceptible and watermark logo can be perfectly extracted. The effect of some common attacks on extracting process, in case of PSNR and NC values, is studied and results are listed in Table I. As inferred from Table I, our proposed watermarking scheme has high robustness when faced attacks like Gaussian and median filtering, histogram modification and gamma correction. The proposed watermarking scheme especially resists the JPEG compression attack as shown in Fig. 6.

In Table II, NC values for extracted watermarked in our method is compared with watermarking method in [10]. Results show that proposed method outperforms method in [10] in case of robustness.

TABLE II. Comparison between our watermarking method and method in [10] in case of NC values under various attacks.

	max(NC1,NC2) [10]	**Proposed Method**
Histogram modification	0.953	1
JPEG QF=80	0.999	1
JPEG QF=50	0.999	1
JPEG QF=20	0.998	0.999
Median filtering	0.963	0.981
Gaussian filtering	0.968	1

VI. CONCLUSION

In this paper, a highly robust image watermarking method in contourlet domain combined with singular value decomposition technique is presented. In this algorithm, singular values of watermark image are embedded in singular values of selected directional subband. The proposed method demonstrates significant perceptual invisibility and high robustness against common attacks such as JPEG compression, rotation, histogram modification, gamma correction, Gaussian and median filtering.

REFERENCES

[1] R. Mehul and R. Priti, "Discrete Wavelet Transform Based Multiple Watermarking Scheme," Proceeding of IEEE, Technical Conference on Convergent Technologies for the Asia-Pacific Bangalore, pp. 14-17, Oct 2003.

[2] H. R. Sadreazami and M. Amini, "Dual Wavelet Watermarking Using Principal Component Analysis," Signal Processing, ICSP 2010. 10th International Conference on, pp. 1821-1824, Oct 2010.

[3] A. A. Reddy and B. N. Chatterji, "A New Wavelet Based Logo-Watermarking Scheme," Pattern Recognition Letters , vol. 26, pp. 1019-1027, May 2005.

[4] M. Amini, H. R. Sadreazami and K. Yaghmaie, "A New Scheme for Dual Watermarking Using DWT-PCA Technique," IMAGAPP - International Conference on Imaging Theory and Applications, pp. 43-46, May 2010.

[5] M. N. Do and M. Vetterli, "The Contourlet Transform: An Efficient Directional Multi resolution Image Representation," IEEE Trans. on Image Processing, vol.14, pp. 2091-2106, 2005.

[6] Sh. Zaboli and M. S. Moin, "CEW: A Non-Blind Adaptive Image Watermarking Approach Based On Entropy in Contourlet Domain", IEEE International Symposium on Industrial Electronics, pp. 1687-1692, 2007.

[7] B. C. Mohan and S. S. Kumar, "Robust Digital Watermarking Scheme Using Contourlet Transform," International Journal of Computer Science and Network Security, vol. 8, pp. 43-51, 2008.

[8] H. Bi, X. Li, Y. Zhang and Y. Xu, "A Blind Robust Watermarking Scheme Based on CT and SVD," Signal Processing, ICSP 2010. 10th International Conference on, pp. 881 - 884, Oct 2010.

[9] F. Rahimi and H. Rabani, "A Visually Imperceptible and Robust Image Watermarking Scheme in Contourlet Domain," Signal Processing, ICSP 2010. 10th International Conference on, pp. 1817 - 1820, Oct 2010.

[10] Z. Jianhong, Y. Xiaoming and X. Xiaofei, "Dual Watermarking Algorithm Based on Contourlet," Intelligent Control and Information Processing (ICICIP), pp. 213 – 216, 2010.

[11] E. Ganic and A. M. Eskicioglu, "Robust Embedding of Visual Watermarks Using DWT-SVD," Journal of Electronic Imaging, vol. 14, 2005.

[12] A. Mansouri, A. A. Aznaveh and F. Torkamani Azar, "SVD-based Digital Image Watermarking Using Complex Wavelet Transform," Sadhana, vol. 34, pp. 393–406, June 2009.