Contourlet Based Image Watermarking Scheme Using Schur Factorization and SVD

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Abstract. In this paper, a novel image watermarking scheme is proposed, based on Contourlet Transform (CT) and Matrix Factorization methods namely, Schur Factorization and Singular Value Decomposition (SVD). The original image and watermark are both decomposed by CT. The lowest frequency coefficients of original image after CT are factorized using SVD and that of watermark after CT are decomposed by Schur Factorization. The schur form of watermark is further factorized using SVD. The modified coefficients of singular values of watermark are embedded in the singular values of original image followed by inverse SVD and inverse CT computation that results in the watermarked image. The experimental results demonstrate that the scheme is resistant against signal processing attacks such as median filter, salt and pepper noise, Gaussian noise, compression and geometric attacks.

Keywords: Digital watermarking, Contourlet Transform, Schur factorization, SVD factorization.

1 Introduction

With the growth and advancement in multimedia technology, the user can easily access, tamper and modify the content. The technique for the copyright protection of the digital product is called Digital Watermarking in which information pertaining to ownership of data is embedded into original work. In transform domain, the image is represented by frequency. Here, Discrete Wavelet Transform (DWT) [1] and Contourlet Transform (CT) have gained much popularity in research arena. CT, proposed by Do, and Vetterli [2], provides directionality and anisotropy besides time frequency localization and multiresolution representation feature of wavelets. Moreover, wavelets have only three directions in each resolution while contourlet provides any number of directional decomposition at every level of resolutions showing that the CT is more advantageous than wavelet [1]. An algorithm based on CT was proposed by Liu and Tan [3] in which the watermark was added to the SVD domain of the cover image. Xu et al. [4] proposed a scheme where the lowpass coefficients of image in CT domain were decomposed using SVD. Liu et al. [5] proposed a scheme in which the original cover image was decomposed by CT and schur factorization was adopted in lowpass subband to embed watermark information.

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2 Contourlet Transform and Matrix Decomposition Techniques

A flexible, multi-resolution, directional image representation for two dimensional piecewise smooth signals is provided by CT [2] as shown in figure 1 and 2.

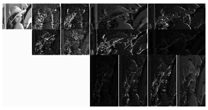


Fig. 1. The CT of the Lena Image

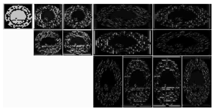


Fig. 2. The CT of the Logo Image

Matrix Decomposition Techniques

Singular Value Decomposition. The SVD [3] of image matrix M of size AxB is

$$M = U\ S\ V^*. \tag{1}$$

Where S is non negative diagonal matrix of size AxB, U is unitary matrix of size AxA and V^* is the conjugate transpose of unitary matrix V of size BxB.

Schur Factorization. The decomposition with Schur factorization [5] can be taken as

$$M = U\ T\ U^K. \tag{2}$$

Where U^k is the conjugate transpose of unitary matrix U. The eigenvalues of M are along the diagonal of upper triangular matrix T, known as Schur form.

3 Proposed Algorithm

The watermarking techniques generally involve embedding watermark coefficients directly to the original image coefficients, but two matrix factorization methods, namely SVD and Schur are used in the proposed scheme after CT to decompose the coefficients of watermark to be embedded. The Schur decomposition is applied on the watermark coefficients after CT. The Schur form is further factorized by SVD. The singular values thus obtained are embedded in the CT and SVD decomposed coefficients of original image. The proposed scheme has been found to be more robust against attacks than schemes that have been implemented with SVD with CT.

3.1 Watermark Embedding

The embedding is done in the lowpass subband to ensure robustness and imperceptibility. The quality of image is maintained by taking a low visibility factor.

Step1**:** The original image and watermark is transformed using CT which represents the image in the form of subbands depending on the number of levels.
Step2: SVD is applied on the CT lowest frequency coefficients of original image.
Step3: The lowest frequency coefficients of CT decomposed watermark image are factorized using Schur decompostion method to obtain Schur form.
Step4: The Schur form is then decomposed using SVD to get the singular values.

Step5: The singular values of the original image are then modified by the singular values of the watermark using α as a visibility factor.

$$P' = P + \alpha W . \quad (3)$$

Where, the singular values of original and embedded image are represented by *P* and *P'* respectively. The singular values of watermark are represented by *W*.
Step6: Inverse SVD and inverse CT is then applied on the modified original image singular values to obtain the embedded image.

3.2 Watermark Extraction

Step1: The embedded image is transformed using CT.
Step2: SVD is applied on the lowest frequency coefficients of the embedded image.
Step3: The singular values of watermark are extracted from the lowest frequency subband of embedded image as shown in equation 4.

$$W = (P' - P) / \alpha . \quad (4)$$

Step4: The inverse SVD, inverse Schur and inverse CT is then applied on the extracted image singular values to get the watermark image.

4 Performance Evaluation and Experimental Results

The scheme is implemented by taking gray scale image of Lena of size 512x512 as cover image and Logo as a watermark of size 256x256 as shown in figure 3 and 4 respectively. The embedded image and extracted image are shown by figures 5 and 6 respectively. The visual fidelity can be measured by calculating the peak signal to noise ratio (PSNR) between the original image and watermarked image, which is 49 dB showing good invisibility factor. To measure the quality of the embedded and extracted watermark, the Normalized Correlation (NC) has been calculated between the original watermark and extracted watermark. For proposed scheme, without applying any attacks, NC is 1.0 showing that the watermark has been extracted precisely and accurately. The Gaussian noise has been calculated for the variance of 0.001 and 0.003. The proposed scheme is seen to have better results as compared to Xu's[4] scheme as shown in Table 1, except for the scaling attack, where the difference is of only 0.0002 for NC. The proposed scheme is hence found to be more robust and exhibits better performance.

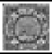
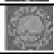
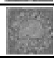
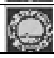
Fig. 3. Original Image

Fig. 4. Original Watermark

Fig. 5. Watermarked

Fig. 6. Extracted Watermark

Table 1. Robustness Comparison of extracted watermark with Xu's [4] Scheme

Attack	Results		
	Proposed Scheme NC	*Images on applying attacks*	*XU's Scheme NC*
Median Filtering (3x3)	0.9798		0.929
Gaussian Noise (var 0.001)	1.0000		0.869
Gaussian Noise (var 0.003)	1.0000		0.698
Scaling (0.75)	0.9998		1.0
Scaling (0.150)	1.0000		1.0
Rotation (1)	0.6437		0.626
Salt and Pepper Noise (density 0.001)	0.9972		0.970
Salt and Pepper Noise (density 0.01)	0.9080		0.749
Salt and Pepper Noise (density 0.02)	0.8019		0.664
JPEG Compression (30)	0.9963		0.907
JPEG Compression (50)	0.9940		0.984
JPEG Compression (70)	0.9990		0.999

5 Conclusion

The proposed method displays better performance than the other schemes which have been implemented with either CT with SVD only or applying Schur Factorization method on CT. Experimental results demonstrate that the extracted watermark is similar to the watermark embedded. The proposed algorithm shows excellent resilience against attacks and has high perceptual quality of watermarked image. The future work involves the use of matrix factorization methods such as QR decomposition and Takagi's factorization.

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