Dual Wavelet Watermarking Using Principal Component Analysis

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Abstract—**In this article, a new scheme of dual wavelet watermarking by applying principal component analysis is presented. First, we identify the two best sub bands of wavelet transform by considering the intensity variance of each sub band. These two sub bands are further transformed by 1-level wavelet transform. The embedding locations are obtained by experiment in a way that they would be compatible with the human visual system. Both watermarks are embedded within the selected sub bands with respect to their principal components. We take advantage of interleaving technique to improve imperceptibility of the algorithm. Experimental results show good robustness and security of the proposed method against various attacks such as JPEG compression, cropping, gamma correction and Gaussian filtering.**

Keywords: Discrete Wavelet Transform, Principal Component Analysis , Dual Watermarking,

I. INTRODUCTION

Digital image watermarking technology is the technique of modifying original image in order to embed watermark bits which are containing information such as authentication data of the owner or copyright codes. Several spatial domain and transform domain digital watermarking algorithms have been proposed so far [1, 2]. Watermarking schemes of transform domain have more advantages than those in spatial domain. Discrete wavelet transform (DWT) has some unique characteristics in order to be compatible with human visual system (HVS). Several works have been proposed to combine DWT with other techniques in order to increase robustness and imperceptibility [3, 4]. Principal component analysis (PCA) is one of transformations which has been used in watermarking [5-8]. The main characteristic of this transform is its high energy concentration and complete decorrelation. To improve the robustness and protection of the watermarking scheme, dual watermarking has been employed [9]. In dual watermarking the primary and secondary watermarks are embedded into host image in a way that the primary watermark is a copyright symbol and the secondary watermark is a fusion image. Also we can take advantage of using efficient band width by embedding two watermarks into host image.

This paper proposed a new method of watermarking in wavelet domain by using PCA technique. First of all, we employ DWT on the host image and select two significant sub bands for embedding two watermarks regarding intensity variance of each sub bands [10]. The selected sub bands are decomposed by 1-level DWT. In order to obtain the embedding locations, we choose those which are more compatible with HVS. In this way, we consider both robustness against attack and the best quality of watermarked image. Then in next step, principal component analysis is applied to both sub bands in order to make the energy of the coefficients concentrate and distribute the watermark energy over embedding sub bands. As a result, we achieve better robustness, perceptual transparency, and good localization.

The remaining of the paper is organized as follows: Section II reviews briefly the Principal Component Analysis. In Section III, the embedding and extracting algorithms are explained in two part A and B. Experimental results are presented in section IV. At the end, section V concludes the paper.

II. PRINCIPAL COMPONENT ANALYSIS

PCA is a method that is used to project a large number of variables to lower dimension of their linear combinations that adequately describe the system. In this way, it re-expresses the data as a linear combination of its basic vectors. The basic idea behind using the principal component analysis is to distribute the watermark energy over all sub bands of wavelet transform, resulting considerable robustness by representing an excellent domain for inserting the watermark. To obtain the PCA components of matrix I , firstly calculate the covariance matrix defined by:

$$C_I = E\{(I-m)\times(I-m)^T\} \tag{1}$$

Where E , m and T denote expectation operation, mean of matrix X and matrix transpose, respectively. The principal components of X are the eigenvectors of C_x which can be derived by:

$$C_i\Phi = \lambda\Phi \tag{2}$$

Where Φ and λ are the matrices of the eigenvectors and the eigenvalues defined as $\Phi = (e_1, e_2, e_3, ..., e_n)$ and $\lambda = (\lambda_1, \lambda_2, \lambda_3, ..., \lambda_n)$. The matrix Φ is an orthogonal matrix called basis function of PCA. Principal component analysis transforms the correlated image into uncorrelated

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coefficients by taking the inner product of the image with basis function denoted by Φ [5, 6].

$$Y = \Phi^T I \tag{3}$$

Where Y is the PC matrix which represents the principle component of matrix I .

III. WATERMARKING SCHEME

Our proposed watermarking algorithm is presented in this section. We have taken advantages of DWT and PCA simultaneously in order to develop a new watermarking method. Embedding and extraction algorithm are described as follow in sub sections A and B.

A. Embedding Process

A grayscale I of size $M \times M$ is assumed as a host image and two binary image watermark of size $P \times P$ are shown in Fig. 1. The embedding algorithm can be divided into the following steps :

- Permute the watermark bits randomly using an interleaver with a secret seed in order to disperse the spatial relationship of bits and to increase the invisibility as shown in Fig. 1.

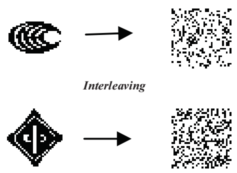


Figure 1. The binary watermark logos, IAEEE and IEEE, and their interleaved versions.

- Perform 1-level wavelet transform on host image as shown in Fig. 2. To choose the appropriate sub bands for embedding the watermark logos, the intensity variance of each sub-band is calculated, and then two sub-bands with the mid values are selected.

Figure 2. The 1-level DWT to select two sub bands.

- Decompose the two sub bands by 1-level further DWT as shown in Fig. 3. Being compatible with HVS, the embedding locations are obtained by experiment.

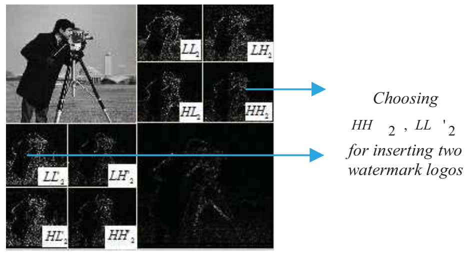


Figure 3. Decomposing the two selected sub bands and choosing the best locations for embedding.

- Divide the two sub-bands into n blocks which $n = P \times P$, is the number of watermark bits.
- Perform PCA transform in all non-overlapping blocks of both sub bands.
- First watermark bits are embedded in an additive way into bits of each block based on their energy order. For instance, the first bit of watermark is added to a bit of the first block which is in the highest energy position or the first principal component of each block [8]. Embedding equation is as follow:

$$\hat{Y} = Y + \alpha . W \tag{4}$$

Where Y and $\hat{Y}$ are the first principal component of each block before and after adding the watermark bits respectively, and α is the watermark weighting factor. This procedure is the same for both watermark logos.

- Apply inverse PCA on two sub bands and then inverse wavelet transform to get the watermarked image.

B. Extraction Process

In extraction part, we are going to obtain an estimate of the original watermark. As our proposed watermarking scheme is non-blind, the host image is required in extraction part. The extracted process is formulated as follows:

- Perform 1-level wavelet transform on watermarked image and identify the two best sub bands by considering the intensity variance of each sub bands.
- Decompose two selected sub bands into four sub bands by 1-level further DWT and choose the sub bands in the same place as embedding part.
- Divide two selected sub bands into n non-overlapping blocks and apply PCA to each block.
- Extract every bit embedded into the first principal component of each block by the following equation:

$$\widetilde{W} = \frac{(\hat{Y} - Y)}{\alpha} \tag{5}$$

- Each watermark logo is just recovered by having access to the secret seed of the deinterleaver.

IV. EXPERIMENTAL RESULTS

The experiments are conducted in matlab R2010 with a grayscale image cameraman of size 512×512 and two binary logos with 32×32 pixels. Peak signal to noise ratio (PSNR) between host (I) and the watermarked $(\hat{I})$ images is computed for evaluating the imperceptibility.

$$PSNR(I,\hat{I}) = 10\log_{10}\left(\frac{M^2.\max(I)^2}{\sum_{i=1}^{M}\sum_{j=1}^{M}(I(i,j)-\hat{I}(i,j))^2}\right) \quad (6)$$

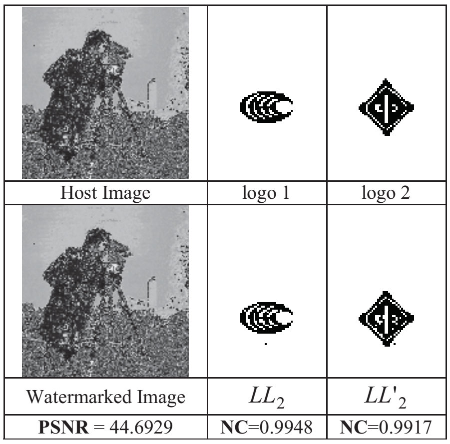
Also normalized correlation (NC) is used for evaluating each logo (W) with its extraction $(\widetilde{W})$.

$$NC = \frac{\sum_{i=1}^{L}\sum_{j=1}^{L} W(i,j).\widetilde{W}(i,j)}{\sqrt{\sum_{i=1}^{L}\sum_{j=1}^{L} W(i,j)^2}.\sqrt{\sum_{i=1}^{L}\sum_{j=1}^{L} \widetilde{W}(i,j)^2}} \quad (7)$$

Fig. 4 shows the watermarked cameraman image and the extracted binary logos at different sub bands. By scrutinising of the results from each sub band, it is obvious that the watermark logos have been perfectly extracted in HH_2 and LL'_2 sub bands as shown in Fig. 5.

Table I presents the PSNR and NC values of the extracted logos at the two best sub bands, HH_2 and LL'_2, after applying some common attacks; JPEG compression, median filter, Gaussian filter, gamma correction, cropping, rotation, Gaussian noise and salt & pepper noise.

Our proposed watermark extraction method can efficiently restore the original watermark even if the scheme is faced to attacks like cropping, Gaussian filtering and gamma correlation. The NC for each extracted logo implies a satisfactory level of watermark robustness. However, the image rotation, salt & pepper and Gaussian noise can break the watermark.



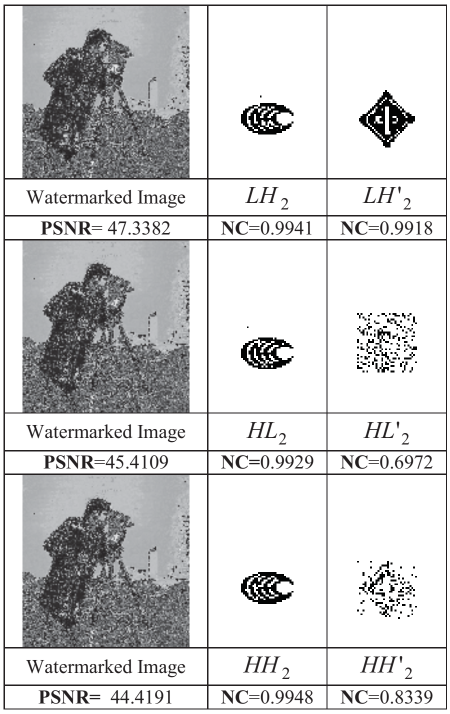


Figure 4. PSNR and NC of the logos in different sub bands.

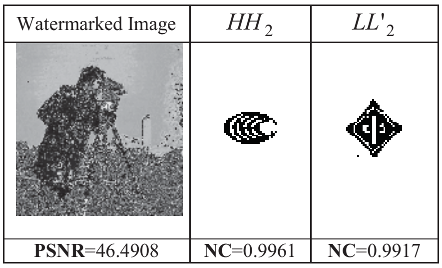


Figure 5. The HH_2 and LL_2 sub bands are the best sub bands for inserting the watermark.

TABLE I. The PSNR and NC values of extracted logos at the two best sub bands, HH_2 and LL'_2 after applying various kinds of attacks to the watermarked image.

Type of attack	PSNR	NC1	NC2
JPEG Compression (Q=100)	41.2068	0.9598	0.8606
JPEG Compression (Q=80)	40.0996	0.8169	0.7396
Median Filter (3×3)	30.3588	0.8283	0.7665
Gamma Correction (γ=2)	13.9083	0.9244	0.8077
Gamma Correction (γ=0.5)	14.9536	0.9388	0.8233
Cropping 25%	14.1468	0.9472	0.9346
Cropping 50%	8.5708	0.8552	0.8797
Rotation 1°	18.1599	0.8090	0.7837
Gaussian Noise (variance=0.001)	5.4684	0.7507	0.7483
Salt & Pepper	5.4682	0.7358	0.7647
Gaussian Filtering (7×7)	37.5331	0.9370	0.8090

V. CONCLUSION

We proposed a new scheme of dual wavelet watermarking based on principal component analysis. After applying discrete wavelet transform to host image, the two best sub bands are identified by considering the intensity variance of each sub band. The selected sub bands are further transformed by 1-level wavelet transform. Having found the embedding locations, each sub band is divided into several blocks in order to apply PCA to each single block. Watermark bits, disseminated by interleaving technique, can be embedded in the first principle component of each block. Experimental results show that proposed method can resist to image processing attacks such as cropping, Gaussian filtering and gamma correction.

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