A NEW SCHEME FOR DUAL WATERMARKING USING DWT-PCA TECHNIQUE

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Abstract: In this paper, we propose a new scheme of dual watermarking by applying discrete wavelet transform and principal component analysis. For the embedding, we identify two best sub bands of wavelet transform by considering the intensity variance of each sub band. Two watermarks are embedded within the selected sub bands with respect to their principal components. Using dual watermark improves robustness and imperceptibility of algorithm and also takes advantage of using efficient bandwidth by embedding two watermarks into host image. Interleaving technique is used to improve imperceptibility of the algorithm. 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, cropping, histogram modification and gamma correction. This robustness is more noticeable when cropping or gamma correction applies to the watermark image.

1 INTRODUCTION

In recent years, digital watermarking technology has attracted great research interests. Watermarking is a way of embedding a key into the original data in order to increase security and copyright protection. Several spatial domain and transform domain digital watermarking algorithms have been proposed (Mehul, 2003), (Dugad, 1998) Watermarking schemes of transform domain have more advantages than those in spatial domain. Discrete wavelet transform (DWT) has some unique characteristics in order to compatibility with human visual system (HVS). Several works have been proposed to combine DWT with other techniques in order to increase robustness and imperceptibility (Loukhaoukha, 2009), (Reddy ,2005). Principal component analysis (PCA) is one of transformations which have been used in watermarking (Hien, 2008), (Kang, 2008), (Mostafa, 2009). The main characteristic of this transform is its high energy concentration and complete decorrelation. To improve the robustness and protection, dual watermarking has been employed (Bhatnagar, 2008). 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 bandwidth by embedding two watermarks into host image.

In this paper, after employing DWT on the host image, we select two significant sub bands for embedding two watermarks not only by using HVS characteristics but also based on intensity variance of each sub bands (Mansouri, 2009). In this way we consider both robustness against attack and the best quality of watermarked image. Then PCA is applied to both sub bands in order to concentrate the energy of coefficients and distributes the watermark energy over embedding sub bands. As a result, we achieve better robustness, perceptual transparency, and good localization. The rest of the paper is organized as follows: Section 2 provides a quick review on PCA. In Section 3, proposed embedding and extracting algorithms are explained. Experimental results are presented in section 4. Finally, section 5 concludes the paper.

2 PRINCIPAL COMPONENT ANALYSIS

Principal component analysis 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 data as a linear combination of its basic vectors. The basic idea behind using the PCA is to distribute the watermark energy over all sub bands of wavelet transform, resulting watermark robustness by representing an excellent domain for inserting the watermark. To obtain the PCA components of matrix X , firstly calculate the covariance matrix as is defined by:

$$C_x = E\{(X-m)\times(X-m)^T\} \quad (1)$$

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:

$$C_x\Phi = \lambda\Phi \quad (2)$$

In which Φ and λ are the matrix of eigenvecors and matrix of 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. PCA transform the correlated image into uncorrelated coefficients by taking the inner product of the Image with basic function Φ .

$$Y = \Phi^T X \quad (3)$$

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

3 WATERMARKING SCHEME

In this section a new dual watermarking is presented. We have used DWT and PCA in order to develop the algorithm. The proposed watermark algorithm can be decomposed into two parts: embedding and extracting.

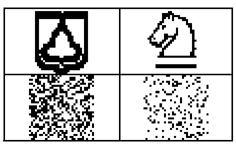


Figure 1: The binary watermark and interleaved logos.

3.1 Embedding Algorithm

We assume that the grayscale host image X of size $N \times N$ and two binary image watermark of size $P \times P$, shown in Figure 1. The embedding algorithm can be divided into the following steps:

1. Permute the watermark bits randomly using an interleaver with a secret seed in order to disperse the spatial relationship and to increase the invisibility.
2. Perform 1-level wavelet transform on host image. To choose the appropriate sub bands for embedding watermark, the intensity variance of each sub-band is calculated, and then two sub-bands with the mid values are selected as the best ones.
3. Divide the two sub bands into n blocks which $n = P \times P$, is the number of watermark bits.
4. Perform PCA transform on all non overlapping blocks of both sub bands.
5. First watermark bits are embedded in an additive way into bits of each block based on their energy order. For example the first bit of watermark is added with a bit of the first block which is in position with the highest energy or the first principal component of each block (Mostafa, 2009). Embedding equation is as follow:

   $$Y_w = Y_o + a.W \quad (4)$$

   Where Y_o and Y_w are, the first principal component of each block before and after adding the watermark bits and a is the embedding intensity factor. This procedure is done in the same way for the second watermark bits.
6. Apply inverse PCA on two sub bands and then inverse wavelet transform to get the watermarked image.

3.2 Extraction Algorithm

As our proposed watermarking scheme is a non-blind watermarking, the host image is required in watermarking extraction. The extracted process is as follows:

1. Decompose the watermarked image (with or without considering attack) into four sub bands.
2. Divide two selected sub bands into n blocks and apply PCA to each block.
3. Extract every bit embedded into the first principal component of each block by the following equation:

$$W_{extract} = \frac{(Y_w - Y_o)}{a} \tag{5}$$

4. Each watermark logo is recovered by deinterleaver and using its secret seed.

4 EXPRIMENTAL RESULTS

Several experiments are conducted to demonstrate the imperceptibility and robustness of the proposed method. In all of these experiments, the original image is 512×512 grayscale image of Lena and the watermark are selected as logos with 32×32 size. Peak signal to noise ratio (PSNR) between the original and watermarked images is computed in order to evaluate the imperceptibility of the algorithm.

$$PSNR(X_w, X) = 10\log_{10}\left(\frac{\max(X)^2}{MSE(X, X_w)}\right) \tag{6}$$

$$MSE(X_w, X) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(X(i,j) - X_w(i,j))^2}{N^2} \tag{7}$$

Also normalized correlation (NC) is used for evaluating the similarity of the watermark and extracted logos.

$$NC = \frac{\sum_{i=1}^{P}\sum_{j=1}^{P} W(i,j).W_{extracted}(i,j)}{\sum_{i=1}^{P}\sum_{j=1}^{P} W(i,j)^2} \tag{8}$$

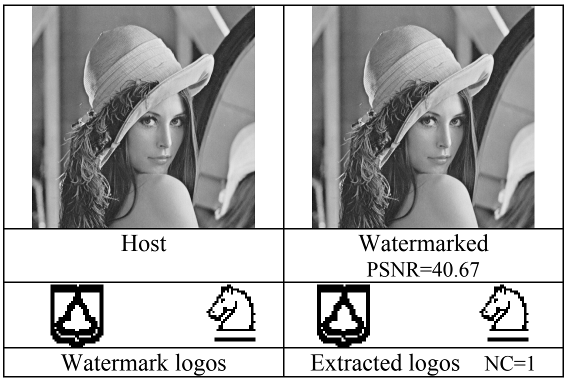


Figure 2: The host image, its watermarked, watermark logos and their extracted. PSNR=40.67 and for both logos NC=1.

Figure 2 indicates that the applied method created no perceptible artefact on the host image. Also both watermark logos have been perfectly extracted. Figure 3 shows the effect of some common attacks on process of extracting. PSNR and NC related to each attack have also been computed. As shown in Figure 3, the proposed watermarking scheme has good robustness when faced with attacks like cropping, histogram modification and gamma correlation. NC for each extracted logo implies a satisfactory level of watermark robustness.

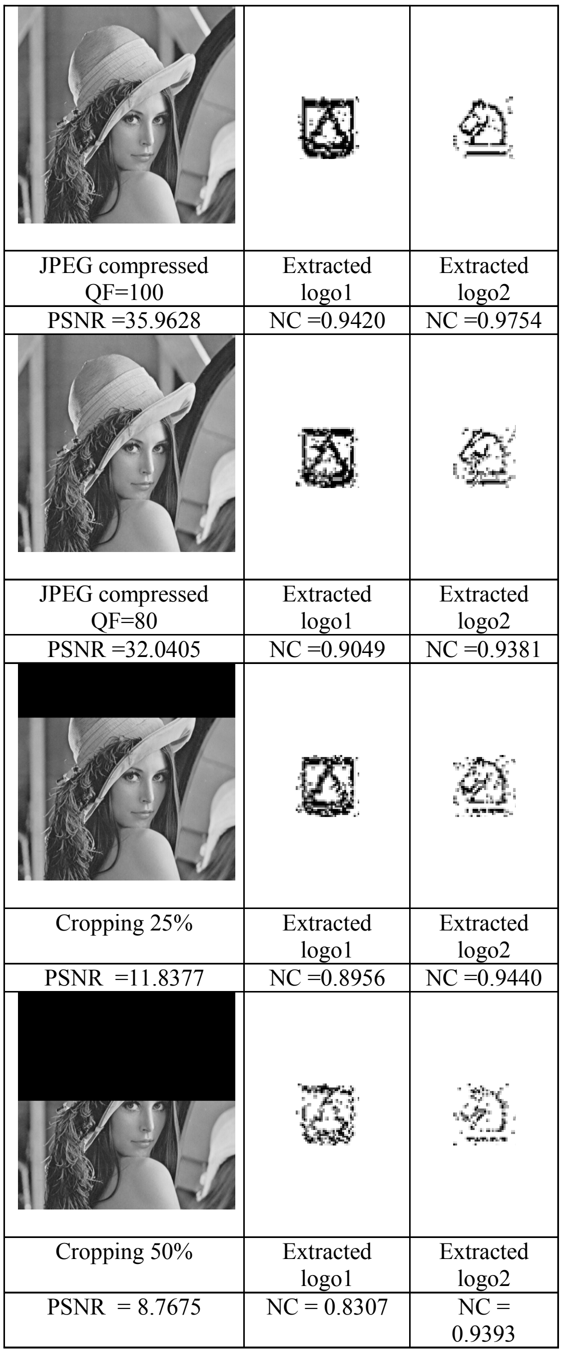


Figure 3: Extracted logos with their corresponding NC and PSNR values after various attacks on watermarked Lena image.

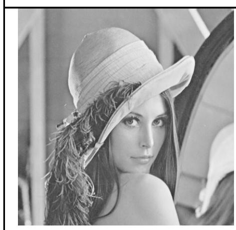
		
Histogram Modification	Extracted logo1	Extracted logo2
PSNR=19.4186	NC =0.8535	NC =0.9301
		
Gaussian Filtering mask 7×7	Extracted logo1	Extracted logo2
PSNR =40.1165	NC =0.8507	NC =0.9209
		
Gamma correction Gamma=1.5	Extracted logo1	Extracted logo2
PSNR =27.7601	NC =0.9158	NC =0.9490
		
Gamma correction Gamma=0.7	Extracted logo1	Extracted logo2
PSNR 19.2352	NC =0.9159	NC =0.9747

Figure 3: Extracted logos with their corresponding NC and PSNR values after various attacks on watermarked Lena image. (cont.)

5 CONCLUSIONS

A new scheme of dual watermarking based on PCA and DWT is presented in which both watermark logos are visually meaningful binary images. Choosing the most significant sub bands is in accordance with intensity variance of each sub band. Dividing each sub band to n blocks, PCA is applied on each single block in order to concentrate the energy of block coefficient. First principle component of each block is selected for embedding watermark. Also interleaving technique is used to improve imperceptibility of the algorithm. Experimental results show no visible difference between the host and watermarked images. It is also demonstrated that proposed scheme is considerably robust against attacks such as cropping, histogram modification and gamma correction.

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