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A Watermarking Algorithm for Digital Image Based on DCT and SVD

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Abstract

In this paper, we propose a watermarking algorithm for digital image based on DCT and SVD. The algorithm can satisfy the transparence and robustness of the watermarking system very well. The experiment based on this algorithm demonstrates that the watermarking is robust to the common signal processing techniques including JEPG compressing, noise, low pass filter, median filter, contrast enhance .Experimental results show that the new watermarking scheme is more robust than the SVD methods.

1. Introduction

With the development of web communication and multimedia technology, more and more digital multi-media signal can be transmitted through Internet. This made multimedia data vulnerable to various attacks. Among today's information security techniques, multimedia authentication techniques have been developed greatly and become a kind of powerful tool for protecting multimedia content. Multimedia authentication techniques can be divided into two groups including digital signature and watermarking. The former utilizes encryption algorithm to extract hash codes from image or other multimedia data as signature, and the hash code is saved in header file or other extra space transmitting with the image. When authentication is needed, signature produced in the same way will be compared with signature saved before. If they match, then received multimedia data is authenticated. The latter is that the feature codes (such as hash value or message authentication code) of object to be authenticated are self-embedded as watermark, and then feature extracted in the same way will be compared with the watermark retrieved to determine if there are any changes. Compared with digital signature method, the authentication scheme with watermark has the advantage that it does not need extra space to save authentication code.

Watermarking, in general, can be grouped into two categories as spatial domain and frequency (transform) domain methods. In spatial domain approaches the watermark is embedded directly to the pixel locations. Least Significant Bit (LSB) modification is well known example of these type methods. In frequency domain approaches, the watermark is embedded by changing the frequency components. Although DCT and Discrete Wavelet Transform are mostly used transform methods, different types of transform techniques like Discrete Fractional Fourier Transform (DFrFT) were examined. Spatial domain methods are not preferred since they are not robust to common image processing applications and especially to lossy compression. Then, transform domain techniques are mostly used for robust watermarking. Another important parameter of watermarking is to determine the embedding place of the watermark. For robustness, it is preferred to embed the watermark into perceptually most significant components, but in this way the visual quality of the image may degrade and watermark may become visible. If perceptually insignificant components are used, watermark may lose during lossy compression. Then determining the place of watermark is a tradeoff between robustness and invisibility, i.e. two important features of a robust watermarking system.

In recent years, SVD was started to use in watermarking as a different transform. The idea behind using SVs to embed the watermark comes from the fact that changing SVs slightly does not affect the image quality. In some methods, the watermark is embedded directly to the SVs of the cover image in others the SVs of transform coefficients are used. While [1] and [2] are blind schemes with a specific quantization method and [5] is semi-blind; [3] and [4] are non-blind schemes as in this study. In this paper we

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propose a watermarking algorithm for digital image based on DCT and SVD to obtain more robusticities than the SVD methods in [5].

This paper is organized as follows: In Section 2 DCT methods are introduced, in Section 3 SVD methods are introduced, in Section 4 digital watermark embedding and extraction scheme are mentioned, in Section 5 some experiment results are mentioned in Section 6 conclusions are presented.

2. DCT methods

Discrete Cosine Transform (DCT): A transformation function which transforms the representation of data from space domain to frequency domain. One dimensional DCT is used in audio compression method. The only dimension of interest is time; two dimens-ional DCT is used in image compression where the vertical and horizontal dimensions are considered.

Formulae of the 2-D DCT:

$$F(u,v)=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}C(u)C(v)f(i,j)\cos\left[\frac{\pi(2i+1)u}{2N}\right]*\cos\left[\frac{\pi(2j+1)u}{2N}\right] \quad (1)$$

Formulae of the 2-D inverse DCT:

$$f(i,j)=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}C(u)C(v)F(u,v)\cos\left[\frac{\pi(2i+1)u}{2N}\right]*\cos\left[\frac{\pi(2j+1)u}{2N}\right] \quad (2)$$

which

$$C(u),C(v)=\begin{cases}\sqrt{1/N}, u,v=0\\ \sqrt{2/N}, u,v=1,2,\cdots,N-1\end{cases}$$

DCT is used in many standardized image, audio, and video compression methods. It has shown its superiority in reduction of the redundancy of a wide range of signals. 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.

3. SVD Methods

Any matrix A of size $m\times n$ can be represented as:

$$A=USV^T \quad (3)$$

where U and V are orthogonal matrices ($UU^T=I, VV^T=I$) by size $m\times m$ and $n\times n$ respectively. S, with size $m\times n$, is the diagonal matrix with r (rank of A matrix) nonzero elements called singular values of A matrix. Columns of U and V matrices are called left and right singular vectors respectively. If A is an image as in our case, S have the luminance values of the image layers produced by left and right singular vectors. Left singular vectors represent horizontal details while right singular vectors represent the vertical details of an image. SVs come in decreasing order meaning that the importance is decreasing from the first SV to the last one, this feature is used in SVD based compression methods. Changing SVs slightly does not affect the image quality and SVs do not change much after attacks, watermarking schemes make use of these two properties.

In embedding stage of the method introduced in [5], SVD is applied to the cover image, watermark is added with a gain parameter to the SV matrix *S*, SVD is applied once, resultant U and V matrices are stored and resultant SV matrix is used with U and V matrices of the cover image to compose the watermarked image. In extraction stage, the steps in embedding are reversed: SVD is applied to watermarked image. An intermediate matrix is composed by using stored U and V matrices and singular matrix of watermarked image. The watermark is extracted by subtracting singular matrix of cover image from the intermediate matrix.

4. Digital watermark embedding and extraction scheme

1) Our digital watermark embedding process is divided into 5 steps and is briefly described below:

Step1: The original image $I(512\times 512)$ is first divided into square blocks of size 8×8 pixels, then the DCT is applied in each block. Then The DC value $F_{m,n}(1,1)$ $(1\le m\le 64, 1\le n\le 64)$) of each block $F_{m,n}(1\le m\le 64, 1\le n\le 64)$ is collected together to get an new matrix A (64×64)。

Step2: Apply SVD to A , $A\Rightarrow USV^T$,and obtain U、V and S。

Step 3: Using *W(*32×32*)* to represent the grey watermark. Then according to $S+\alpha W\Rightarrow U_1S_1V_1^T$,obtain U_1、S_1和V_1， and then obtain $\hat{A}$ (64×64) according to $\hat{A}\Leftarrow US_1V^T$ （$\alpha=0.1$）。

Step 4:

Using $\hat{A}(m,n)$ $(1 \le m \le 64, 1 \le n \le 64)$ to replace the DC value($F_{m,n}(1,1)$ $(1 \le m \le 64, 1 \le n \le 64)$),in this way ,the $F_{m,n}$ $(1 \le m \le 64, 1 \le n \le 64)$ which obtained in step 1 become $F^{*}_{m,n}$ $(1 \le m \le 64, 1 \le n \le 64)$ 。

Step5: Apply inverse 8×8 block DCT $F^{*}_{m,n}(1 \le m \le 64, 1 \le n \le 64)$ to produce water-marked image I^{*} (512×512)

2) Our digital watermark embedding process is divided into 3 steps and is briefly described below:

Step1: Apply 8x8 block DCT to watermarked images $I^{*}(512 \times 512)$ and Then The DC value of each block is collected together to get an new matrix $A^{*}(64 \times 64)$ 。

Step2: Apply SVD to the A^{*}, $A^{*} \Rightarrow U^{*}S_1^{*}V^{*T}$, and obtain U^{*}、S_1^{*} and V^{*} 。

Step3: Associating with U_1、V_1 and S_1^{*} , obtain D^{*} according $D^{*} \Leftarrow U_1 S_1^{*} V_1^{T}$, in the end we can obtain the watermark which is embedded according to $W^{*} \Leftarrow \frac{1}{\alpha}(D^{*} - S)$.

5. Experimental results

In this study, the cover image size is 512×512 and DCT block size is 8×8 . Then the size of approximate image generated with DC values is 64×64 and so the size of watermark. MATLAB and Image Processing Toolbox are used for the experiments and attacks. We compare our method with the simplex SVD method proposed by Ruizhen Liu and Tieniu Tan, in order to put the performance investigation of our algorithm by
computing the PSNR (Peak Signal-to-Noise ratio) between the original image and the watermarked image and the normalized correlation coefficient $c(W, W^{*})$ between the original watermark and the extracted watermark.

The algorithm is tested on a variety of images, but for the sake of space, here we only give the results obtained using the 512×512 grayscale image Lena and 32×32 grayscale watermark Plane and test robustness under five practical conditions: JEPG compressing, adding noise, low pass filter, median filter, contrast enhance.

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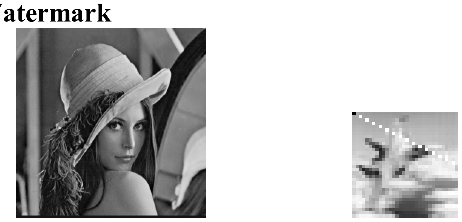
The results as: Figure 1--Figure 8

(a) **(b)**

Figure 1. (a)The Original image (b)The Original Watermark

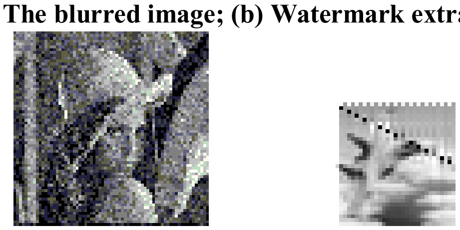


(a) (b)

Figure2. (a)The Watermarked image; (b)Watermark extracted

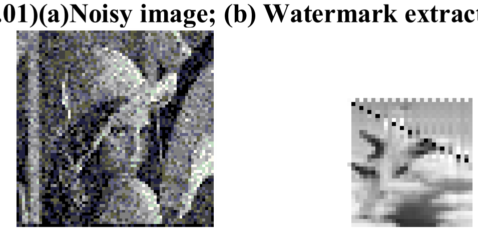
(a) (b

Figure 3. Robustness test against low-pass filtering. (a) The blurred image; (b) Watermark extracted.



(a) (b)

Figure 4. Robustness test against Gaussian noise (0.01)(a)Noisy image; (b) Watermark extracted.



(a) (b)

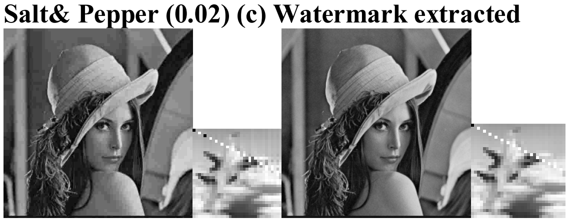
Figure 5. Robustness test against Median Filter (3×3)
(a)Blurred image; (b) Watermark extracted.

(a) (b)

Figure 6. Robustness test against Contrast enhance
(a) The Watermarked image attacked;
(b) Watermark extracted.

(a) (b) (c)

Figure 7. Robustness test against Salt & Pepper (0.02) and Median Filter (3×3);
(a)The Watermarked image attacked by Salt& Pepper (0.02) (b) The Filtered image attacked by Salt& Pepper (0.02) (c) Watermark extracted



(a) (b) (c) (d)

Figure 8. Robustness test against JEPG (20%) and JEPG (60%) (a) The Watermarked image attacked by JEPG (20%); (b) Watermark extracted (c) The Watermarked image attacked by JEPG (20%) (d) Watermark extracted.

Table 1.The corresponding test results that compare our method with the simplex SVD method proposed by Ruizhen Liu and Tieniu Tan

	Our method		SVD method	
Test method	PSNR	C(W,W^*)	PSNR	C(W,W^*)
No attack	42.5432	0.9954	41.7864	0.9932
Gussian Lowpass	49.1032	0.9766	45.0032	0.9634
JEPG (60%)	37.3423	0.9800	37.3222	0.9798
Gaussian noise	43.3225	0.9875	43.2314	0.9783
Contrast enhance	45.3421	0.9654	44.3210	0.9621
Salt & Pepper	42.3785	0.9763	41.2316	0.9638
Median Filter	38.4376	0.9777	37.8967	0.9872

6. Conclusions

In this paper , a watermarking algorithm for Digital Image Based On DWT and SVD is proposed, which is robust to the common signal processing techniques including JEPG compressing, noise, low pass filter, median filter, contrast enhance. In order to testify the merit of our method, comparative experiments with the SVD method are made. Results show that the proposed method is more robust against attacks than the SVD method.

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