A Binary Digital Watermarking Scheme Based On The Orthogonal Vector And ICA-SCS Denoising

Han dongfeng , Li wenhui

Department of Computer Science, University of JiLin, China

E-mail: {hhhhhhdf,handongfenggood}@sohu.com

Abstract

This paper proposed a new perceptual digital watermarking scheme based on ICA, SCS, the human visual system (HVS), discrete wavelet transform (DWT) and the orthogonal vector. The original gray image first is divided into 8×8 blocks, and then permuted. A 1-level DWT is applied to each 8×8 block. Each watermark bit is modulated by orthogonal vector, then the watermark is add to the original image. Finally the IDWT is performed to form the watermarked image. In the watermarking detection process the independent component analysis (ICA)-based sparse code shrinkage (SCS) technique is employed to denoise, and make using of the orthogonal vector character. By hypothetical testing, the watermark can be extracted exactly. The experimental results show that the proposed technique successfully survives image processing operations, image cropping, noise adding and the JPEG lossy compression. Especially, the scheme is robust towards image sharping and image enhancement.

1. Introduction

The digital watermarking has been proposed as a solution to the problem of copyright protection of multimedia data in a networked environment. By the term "digital watermark," we mean a signal which is superimposed on the digital image, in such a way that the following hold.

(1) The visual perception of the image remains unaltered, and the watermark is unnoticed.

(2) We are in a position to detect a certain digital watermark by examining the alterations caused by the superposition.

(3) A great number of different digital watermarks, all distinguishable from each other, can be produced.

(4) Distortion or removal of the digital watermark through general image operations and manipulations should be extremely difficult and, preferably, impossible.

The satisfaction of the above-mentioned demands provides a way to superimpose an "invisible" watermark on images. On the other hand, we must know that no watermarking scheme can survive all attacks, and the watermarking scheme should associate with the cryptography. A certain watermarking scheme should be used under some circumstances. When it comes to copyright protection, there are many problems to solve. Because some issuses should be solved before it applies to actual application. We think for the copyright authorization a image should first registers in the watermark authentication center, then it is regarded as the protected image. When verifying a image, the watermark authentication center should extract the watermark based on the registration information, or it is regarded as a counterfeit. Generally this watermark model can applied to copyright protection, or the watermark authentication center.

There are several techniques have been developed for watermarking mainly in spatial domain and frequency domain. In [1], three coding methods for hiding electronic marking in document were proposed. In [2]–[4], the watermarks are applied on the spatial domain. The major advantage of the spatial domain method is that the algorithm is sample and the the major disadvantage of spatial domain watermarking is that a common picture cropping operation may eliminate the watermark. On the other hand the frequency domain method is more robust than the spatial domain method. So many researchers focus their attentions on this method

The proposed scheme of this paper is based on ICA, SCS, the human visual system (HVS), discrete wavelet transform (DWT) and the orthogonal vector. This method can exactly extract the watermark. Especially, it can resist the signal enhancement operation.

This paper is organized as follows: section 2, section 3 and section 4 describes the HVS, the watermark embedding and detection algorithm. In section 5 experimental results are shown. Finally, in section 6 we draw the conclusion of this paper.

2. The Human Visual System (HVS)

The wavelet transform finds its way into the field of signal analysis. Compared with the traditional transforms, the Fourier transform for instance, the wavelet transform has an advantage of achieving both spatial and frequency localization.

The DWT is very suitable to the human visual system. In [9] the authors proposed a method calculating the image masking and the JND (just noticeable differences). It can be calculate through these terms:

$$q_l^\theta(i,j) = \Theta(l,\theta)\Lambda(l,i,j)\Xi(l,i,j)^{0.2} \quad (1)$$

$$\Theta(l,\theta) = \left\{\begin{matrix}\sqrt{2}, \text{if } \theta = 1 \\ 1 \quad , \text{otherwise}\end{matrix}\right\} \bullet \left\{\begin{matrix} 1.00 & , \text{if } l=0 \\ 0.32 & , \text{if } l=1 \\ 0.16 & , \text{if } l=2 \\ 0.10 & , \text{if } l=3 \end{matrix}\right\} \quad (2)$$

$$\Lambda(l,i,j) = 1 + L(l,i,j) \quad (3)$$

$$L(l,i,j) = \frac{1}{256} I_3^3\left(1 + \left\lfloor \frac{i}{2^{3-l}} \right\rfloor, 1 + \left\lfloor \frac{j}{2^{3-l}} \right\rfloor\right) \quad (4)$$

$$\Xi(l,i,j) = \sum_{k=0}^{3-l} \frac{1}{16^k} \sum_{\theta=0}^{2} \sum_{x=0}^{1} \sum_{y=0}^{1} \left[I_{k+l}^\theta\left(y + \frac{i}{2^k}, x + \frac{j}{2^k}\right)\right]^2 \quad (5)$$
$$\bullet \mathrm{Var}\left\{ I_3^3\left(1 + y + \frac{i}{2^{3-l}}, 1 + x + \frac{j}{2^{3-l}}\right)\right\}_{\substack{x=0,1 \\ y=0,1}}$$

l and θ are the resolution level where l=1, 2, 3 and the frequency orientation where θ=1, 2, 3. From above we can get the JND :

$$JND_l^\theta(i,j) = \frac{1}{2} \bullet q_l^\theta(i,j) \quad (6)$$

The detail of the calculation can refer [5].

3. Watermark Permution And Embedding

We use a binary meaningful image of size 64×64. In order to resist cropping operation, a fast two-dimensional (2-D) pseudorandom number traversing method is used to permute the watermark to disperse its spatial relationship, i.e.

$$W' = \text{Permute}\,(W, \text{Key}\,(K)) \quad (7)$$

During the detection process we can extract W', and then reverse W' to W using :

$$W = \text{InvPermute}\,(W', \text{Key}\,(K)) \quad (8)$$

First we set two orthogonal vector S0 and S1 like below:

$$S0 = [0\;1\;0\;0\;1\;1\;1\;1\;0\;0\;0\;1\;1\;1\;0\;0]$$

$$S1 = [1\;0\;1\;1\;0\;0\;0\;0\;1\;1\;1\;0\;0\;0\;1\;1]$$

S0 , S1 are selected by the Zig-zig scan and then projecting to one dimension, which can warrant this method have a good virtue towards JPEG compression. Patterns S0 and S1 are so selected as to be symmetric and orthogonal to each other. The embedding process follow:

(1) For each 8×8 block we apply 1-level DWT, then we get three detail subbands HL,LH,HH and one approximate subband LL.

(2)select one detail subband of size 4×4, for example HL. The coefficiens are modified :

$$\overline{W}(i,j) = \left\{\begin{matrix} HL(i,j) + alpha * JND(i,j) * S0((i-1)*4+j) \\ \text{if } W'=0; \\ \\ HL(i,j) + alpha * JND(i,j) * S1((i-1)*4+j) \\ \text{if } W'=1; \end{matrix}\right\} i,j=1..4 \quad (9)$$

Where alpha is a positive number controlling the trad-off between perception and the robust of the watermark. For a image of size 512×512 we can embed 64×64 bits information. So three versions watermark are embedded.

(3)Performing the IDWT and forming the watermarked image $\bar{I}$.

4. Watermark Detection

The watermark detection process need the original image I .In the watermark detection process two-setp detection is used.

(1) denoising the possibly corrupted image $\tilde{I}$.

(2) extracting the watermark.

(1) First step the PSNR of a given possibly corrupted image $\tilde{I}$ is caculated. If PSNR is smaller than a given threshold $PSNR_0$, then the independent component analysis (ICA)-based sparse code shrinkage (SCS) technique [7]] [8] is employed to model the denoising problem. Therefore, the noisy image $\tilde{I}$ can be denoted As:

$$\tilde{I} = I + N = As + N \quad (10)$$

Suppose only the observed data is given; the basis matrix and the ICs can be obtained by first finding a separating matrix W (with $W^{-1} = A$) via sparse coding [7]. Then, can be determined by $s = WX$. After sparse coding, the noisy image $\tilde{I}$ can be transformed by means of W, and a noisy independent component, $s + \tilde{N}$ (in the ICA transformed domain), can finally be derived as follows:

$$W\tilde{I} = WI + WN = WAs + WN = s + \tilde{N} \qquad (11)$$

Then, one can shrink $s + \tilde{N}$ by means of g and then get the cleaned version of s, which is represented as $\bar{s}$, where

$$\bar{s} = g\left(s + \tilde{N}\right) \qquad (12)$$

In general, the shrinkage function, is explicitly defined [8] based on the sparse density distribution of noisy independent components to have the effects that small arguments are set to zero and the absolute value of large arguments are reduced by an amount depending on the noise level. In the third step, the approximated host image $\bar{I}$ can be derived by an inverse ICA transformation: $\bar{I} = A\bar{s}$. After the estimated host image is determined, it can be used for watermark detection.

(2) After the pre-processing, we then can extract the watermark from image $\bar{I}$, for each bit the algorithm includes the following steps:

1) For the original image I and the watermarked image $\bar{I}$ each 8×8 block we apply 1-level DWT, we get three detail subbands HL, LH, HH, $\overline{HL}, \overline{LH}, \overline{HH}$ and one approximate subband LL, $\overline{L}L$.

2) using (13)

$$\begin{aligned} PH0 &= ABS\left(SUM\left(\left(HL - \overline{H}L\right).*S0\right)\right) \\ PH1 &= ABS\left(SUM\left(\left(HL - \overline{H}L\right).*S1\right)\right) \\ \tilde{W}'(i,j) &= 0; \quad \text{if} \quad PH0 - PH1 > 0 \\ \tilde{W}'(i,j) &= 1; \quad \text{if} \quad PH1 - PH0 > 0 \end{aligned} \qquad (13)$$

one bit watermark can be extracted.

(3)Then we can extract 64×64 bits watermark. So the extracted watermark $\overline{W}'$ can obtain by

$$\overline{W}' = \text{InvPermute}\left(\tilde{W}, \text{Key}\left(K\right)\right) \qquad (14)$$

We define the similarity measurement between the referenced watermark W and extracted watermark $\overline{W}'$ as

$$NC = \frac{\sum_i \sum_j \left(W(i,j) \oplus \overline{W}'(i,j)\right)}{M \times N} \qquad (15)$$

Where $M\times N$ is the size of the watermark.

5. Experimental Results

We have performed experiments with the test images Lena, Baboon, and Peppers of size 512×512. The watermark "JLU" image of size 64×64. All the test images and the watermark image are shown in fig.2. 18 commonly used attacks are adopted to test the robustness of our method. These attacks included 1) median filtering; 2) Wiener filtering; 3) sharpening 3times; 4) sharpening 4times; 5) Possion noise addition; 6) Salt noise addition; 7) enhanced brightness +50; 8) enhanced brightness +100; 9) enhanced darkness +50; 10) enhanced darkness +100; 11)-14) JPEG compression with quality factors of 90%, 80%, 70% and 60%; 15) dithering; 16) rotation 1 degree; 17) scale from 512×512 to 400×400; 18) scale from 512×512 to 128×128. It can be seen from the experience our method receives good robustness under signal enhancement operations, for example sharpening 3 times the PSNR is only 13.285 and the NC value is 1. When sharpening 4 times the PSNR is 8.699 and the NC can also get a high value 0.9031. Another signal enhancement experience is enhanced darkness +50 the NC is 1. When enhanced darkness +100 the NC is also 1. So from this results we can see our method is very robust towards signal enhancement. Additionally, we also test the robust under noise adding attack. Because our method uses sparse code shrinkage (SCS) technique, the experiences show it has a good performance in denoising. The corresponding results can also be seen from fig.1.

We compare our method with the method proposed in [6]. The strongly enhanced contrast experiences of our method can get the value of NC is 1, and the method proposed in [6] only get the value of NC is 0.97. When sharpening experiences, our method the value of NC is 1, and the method proposed in [6] not mentioned. It can be seen from table.1 our method have a better performance than the method proposed in [6], especially under signal enhancement attacks.

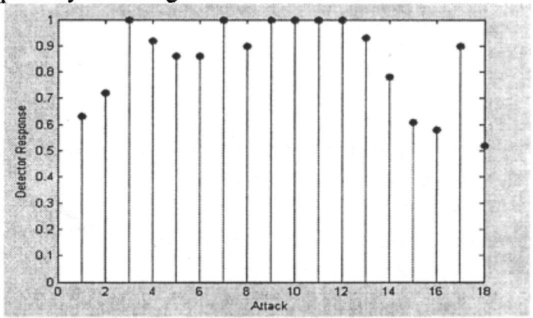

Fig.1. The detection response of results under 18 attacks.

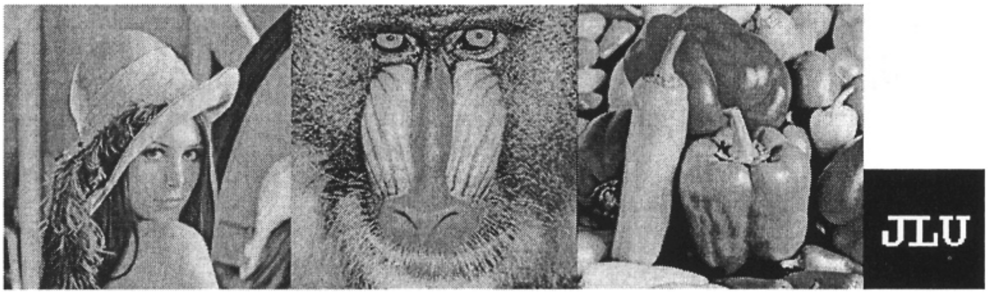

Fig.2. The test images are respectively Lena, Baboo, Peppers of size 512×512 and the watermark image of size 64×64.

Table.1.

Comparison robustness to JPEG lossy compression, PSNR, slightly enhanced contrast, strongly enhanced contrast, sharpening 3 times and cropping (1/4) of our method and the method prorosed in [6].

Image	Method	JPEG (ratio3.3)		PSNR	Slightly enhanced contrast	Strongly enhanced contrast	Sharpening 3 times	Cropping (1/4)
Lena	Proposed in[6]	PSNR	33.8	39.8	0.9985	0.973	No	0.7623
		NC	0.99					
	Our method	PSNR	34.1	40.4	1	1	1	0.7942
		NC	0.999					
Baboon	Proposed in[6]	PSNR	34.8	40.2	0.9992	0.980	No	0.7746
		NC	0.992					
	Our method	PSNR	35.2	40.2	1	1	1	0.7931
		NC	0.9995					
Peppers	Proposed in[6]	PSNR	34.1	38.9	0.9982	0.968	No	0.7741
		NC	0.99					
	Our method	PSNR	33.9	37.6	1	1	1	0.7602
		NC	0.999					

6. Conclusion

In this paper, we proposed an adaptive watermarking algorithm for binary image watermark. The proposed algorithm is evaluated from the transparency point of view and the robustness against some common attacks, such as a JPEG compression, filtering, noise corruption and cropping. The results show the desirable features of proposed algorithm, especially it shows robustness against signal enhancement. The performance of the proposed algorithm is compared with the algorithm proposed in [6]. The comparison results show the advantage of the proposed algorithm over the algorithm in [6].

7. References

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