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A NOVEL DIGITAL IMAGE WATERMARKING SCHEME

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Abstract: Cepstrum analysis is first introduced into digital image watermarking and a novel data hiding scheme of a digital image watermarking in the cepstrum domain is proposed in this paper. A block complex cepstrum-based algorithm is developed to embed a gray-level image into the 1-Dimensional cepstrum components of the original image signal. Computer simulations show that the proposed algorithm is of imperceptibility and is robust to most watermarking attacks, especially to image cropping, JPEG compression and multipliable noise.

Keywords: digital watermarking, information hiding, digital image.

1. Introduction

In recent days, there has been significant interest in watermarking. This is primarily motivated by a need for providing copyright protection to digital contents, such as audio, image and video. Digital image watermarking is a technique for labeling digital pictures by hiding secret information into the images. The embedded data should be imperceptible, robust. Imperceptible means they bring no subjective distortion to media signal, and robust means they are able to survive common signal processing as well as intentional attaacks. Now, there are so many digital watermarking algorithms but quite few did in the cepstrum domain. Moreover the algorithms in cepstrum domain are all about audio watermarking. The authors first introduce cepstrum analysis into digital image watermarking and propose a novel scheme. In the proposed scheme, a permutation function is adopted to rearrange the locations of pixels of the watermark, a block complex cepstrum-based algorithm is developed to embed a gray-level image instead of a binary bit sequence into the 1-Dimensional cepstral components of the original image signal. Computer simulations show that the proposed method is practicable and has promising performance.

2. Cepstrum Representation

Cepstral analysis is a non-parametric technique originally introduced by Bogert, Healy and Tukey, which is very rich in terms of properties and applications. It is effective on a wide class of signals and has been used in speech (speech analysis and recognition), geophysics, sonar, biomedicine, image processing, etc [1].

The complex cepstrum, $c_h(m)$, of the signal $h(n)$ is defined as the inverse Z transform of $\log Z_1[h(n)]$ and is given by:

$$c_h(m) = Z_1^{-1}\{\log Z_1[h(n)]\} \qquad (1)$$

The complex cepstrum can also be obtained using the inverse Fourier transform

$$c_h(m) = F_1^{-1}[\log|H(\omega)| + j\phi_h(\omega)] \qquad (2)$$

where $H(\omega) = |H(\omega)| \cdot \exp\{j\phi_h(\omega)\}$ is the Fourier transform of $h(n)$. Note that the logarithm is complex logarithm. $Z_1[\cdot], Z_1^{-1}[\cdot]$ denote the 1-D Z transform and inverse Z transform respectively; $F_1[\cdot], F_1^{-1}[\cdot]$ denote the 1-D Fourier transform and inverse Fourier transform, respectively. In practice people often define the real part of complex logarithm to be the real cepstrum for convenien. If $h(n)$ is real, its complex cepstrum is also real.

The principal advantage of cepstral coefficients is that they are generally decorrelated. Besides, high-order cepstra are numerically quite small and have a wide range of variances when going from low to high-order cepstral coefficients [2]. Cepstrum coefficients experience much less variance after most common signal processing attacks than original samples in time domain [3], so we propose to embed data in cepstrum domain.

3. Watermarking Embedding Method

In this paper, we propose a novel data hiding scheme of a digital image watermarking in the cepstrum domain. We use a gray-level image as watermark to insert into the cepstral components of the original image signal. In our approach, a block complex cepstrum-based algorithm is developed to embed the image watermarking.

Let X be the original gray-level image of size $M_1 \times M_2$, and the digital watermark W be a gray-level image of size $N_1 \times N_2$, $(N_1 < M_1, N_2 < M_2)$. The original image X and digital watermark W are represented as:

$$X = \{x(i,j), 1 \le i \le M_1, 1 \le j \le M_2\}, \quad (3)$$

$$W = \{w(i,j), 1 \le i \le N_1, 1 \le j \le N_2\} \quad (4)$$

where $x(i,j) \in \{0,1,\cdots,255\}$, $w(i,j) \in \{0,1,\cdots,255\}$ is the intensity of the according pixel (i,j). Our proposed watermark embedding method is as follows:

Step 1: pseudo-random permutation of the watermark

To survive picture cropping, a permutation function is used to permute the watermark to disperse its spatial relationship. According to reference [4], pixel (i', j') is permuted to pixel (i,j). i.e.

$$W' = Permute(W)$$

$$W' = \{w'(i,j) = w(i', j'), 0 \le i, i' \le N_1, 0 \le j, j' \le N_2\} \quad (5)$$

$$\begin{pmatrix} i \\ j \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} i' \\ j' \end{pmatrix} \mathrm{mod} \begin{pmatrix} N_1 \\ N_2 \end{pmatrix} \quad (6)$$

where $ad - bc = \pm 1$; $a, b, c, d \in Z$ (positive integer). When $a = b = c = 1$, $d=2$, equation (6) is the famous Arnold permutation.

Step 2: translation 2-D block signals into 1-D signals

First, divide original image ***X*** into $N_1 \times N_2$ blocks with size of $\frac{M_1}{N_1} \times \frac{M_2}{N_2} = l \times l$ and use $X'_m (0 < m \le N_1 \cdot N_2)$ to represent the mth block. Then, make each block of original image and the watermark into a 1-Dimentional signal (In sequence of row), that is to say:

$$X'_m = \{x'_m(k), 1 \le k \le l^2 | x'_m((i-1) \cdot l + j) = x_m(i,j)\} \quad (7)$$

$$W'' = \{w''(k), 1 \le k \le l^2 | w''((i-1) \times l + j) = w'(i,j)\} \quad (8)$$

Step 3: watermark embedding

Evaluate the cepstrum sequence X''_m of each sub 1-D signal X'_m and add the sequence W'' to the cepstrum sequence X''_m to obtain the embedded 1-D sequence Y''_m. Each pixel of watermark is used to modulate one image block. Experimental studies show that most common signal processing could change individual cepstral coefficient dramatically, but their statistical mean often experiences much less disturbance [3]. So we propose to embed data based on mean manipulation.

$$Y''_m = X''_m + (w''(m) / mppp) \times 10^{-\alpha} \quad (9)$$

where $mppp$ is difference between maximum and minimum of W'', α is the factor controlling the strength of watermark embedding.

Step 4: achieving the watermarked image

Evaluate the inverse cepstrum transform sequence Y''_m of each sub 1-D signal Y''_m and make each 1-D sequence Y'_m into 2-D block $Y_m(i,j)$ with size of $l \times l$.

$$Y_m = \{y_m(i,j), 1 \le i, j \le l | y_m(i,j) = y'_m((i-1) \cdot l + j)\} \quad (10)$$

Then connect all $Y_m(i,j)$ blocks into watermarked image

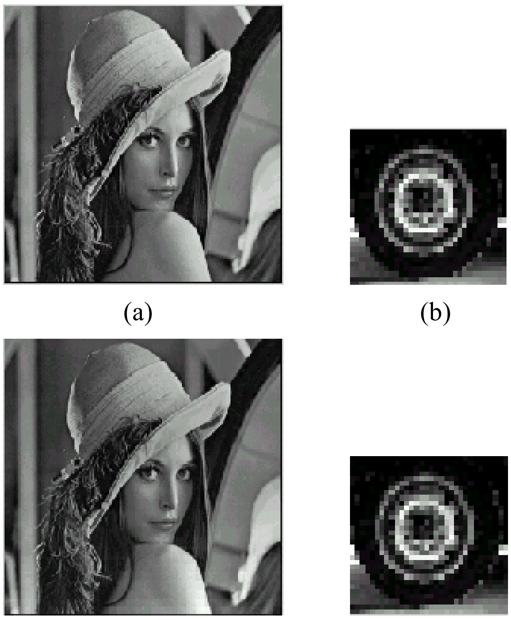
Y of size $M_1 \times M_2$.

4. Watermark Image Extracting

The extraction of the watermark requires the original image, controlling factor α, the size and the contrast of watermarking image and the permutation mapping function. The mean of the original image cepstral coefficients is subtracted from the mean of the received image cepstral coefficients so the extracted watermark $\widetilde{W}$ can be obtained.

In our scheme the watermark is a gray-level image, so observers can compare the extracted watermark with the referenced one subjectively. However in order to make up with the disadvantage of the subjective measurement, we can also use the similarity measurement NC between the referenced watermark W and extracted watermark $\widetilde{W}$ to provide the objective judgment, NC is defined as [5]:

$$NC = \frac{\sum_i \sum_j W(i,j)\widetilde{W}(i,j)}{\sum_i \sum_j [W(i,j)]^2} \tag{11}$$



(a) (b)

(c) (d)

Fig. 1. Example of the proposed watermarking approach
(a) test image Lena (b) watermark
(c) watermarked image (d) extracted watermark (with NC=0.9738)

5. Simulation Results

In this paper, the 256×256 Lena is used as the test image and 32×32 tire is used as the watermark. Arnold permutation $(a = b = c = 1, d = 2)$ is adopted to permute the watermark, α is set to 3. Fig.1 shows an example of embedding and extracting results.

5.1 Image Enhancement

Smoothing operations are used to diminish spurious effects, which may occur in images from poor transmission channels. Fig. 2 shows the watermark extracted from the watermarked image filtered by Gaussian filter with size of 3×3.

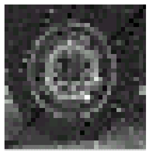


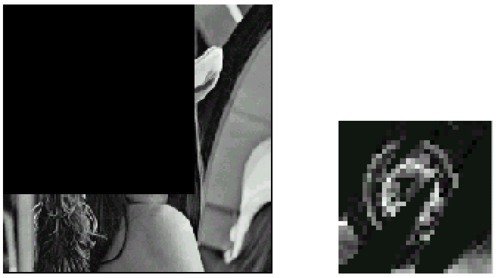
Fig. 2. extracted watermark after Gaussian 3×3 filter

5.2 Image Cropping

As described in section 3, a permutation function is used to disperse the spatial relationship of the watermark. Therefore, it would be hard for a "pirate" to detect or remove the watermark by cutting some part of the image. Table 1 shows the relationship between the similarity measurement NC and the cropping ratio. The higher the cropping ratio is, the lower the NC value is. However, as show in Fig. 3, though a half of the watermarked image is discarded the extracted watermark is still recognizable when the discarded part is replaced with the corresponding part of the original image.

Tab. 1. Relationship between cropping ratios and NC values

Remaining part (%)	NC	Remaining part (%)	NC
100	0.9738	50	0.8410
90	0.9621	40	0.7659
80	0.9465	30	0.7014
70	0.9303	20	0.6387
60	0.8876	10	0.5817



(a) (b)

Fig. 3. (a) a half of an embedded image is discarded

(b) the extracted watermark (NC=0.8410)

5.3 JPEG Compressing:

Fig. 4 shows the extracted results from JPEG compressed version of the watermarked images with the compression quality factor from 0 to 100%. Obviously, NC value decreases as the compression ratio increases. When the compression ratio is high enough, the watermark will be destroyed and become indiscernible. However, the quality of the JPEG compression image will be degraded severely so that the image will be useless.

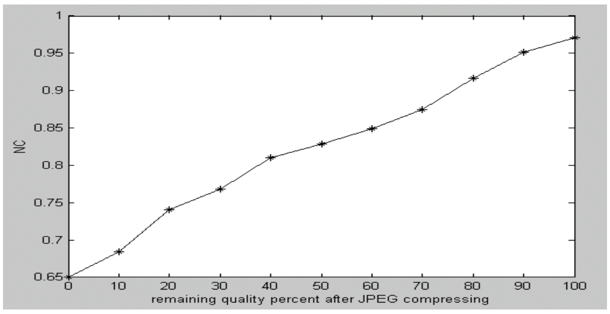
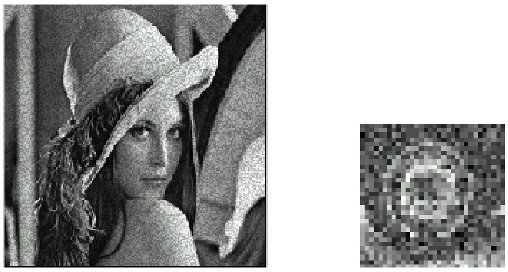


Fig. 4. the NC value after JPEG compression

5.4 Adding Noise

Fig. 5 shows the results of adding the Gaussian white noise and speckle (multipliable) noise to a watermarked image respectively. We can see that this approach is stronger for multipliable noise.

(a) (b)



(c) (d)

Fig. 5 results of adding noise

(a) adding Gaussian noise (b) extracted watermark from (a)

(c) adding multipliable noise

(d) extracted watermark from (c).

6. Conclusions

In this paper a novel digital watermarking scheme in cepstrum domain is proposed and computer simulation results are given. In this scheme a gray-level image can be used as the watermark. Experimental results show that the proposed scheme is robust to most watermarking attacks, especially to image cropping, JPEG compression and multipliable noise.

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