A Watermarking System Based on Complementary Quantization

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Abstract: Blind watermarking utilized the quantization table to embed the watermark by adding or subtracting a quantized constant value. When the watermarked image processes malicious manipulations the constant quantization table is not robust. In this paper, a new adaptive and duplicate quantized blind watermarking system is proposed to attend higher transparency. We use an adaptive quantization table to advance the robustness according to the properties of the human visual system and just noticeable distortion. And the error-correcting based watermarking will have the property that corrects errors of the extracted watermark automatically. A multiresolution watermarking based on the wavelet transformation is selected and therefore it can resist the destruction of image processing. In our experiments, the results show that the robustness and transparency of the adaptive watermarking is much better than the traditional one.

1. Introduction

The rapid development of Internet introduces a new set of challenging problems regarding security. One of the most significant problems is to prevent unauthorized copying of digital production from distribution. Digital watermarking has provided a powerful way to claim intellectual protection [1-20].

A "complementary modulations" robust watermarking was proposed by Lu et al.[14] in order to solve the inadequacy of the available modulation techniques commonly used in ordinary spread spectrum watermarking methods and visual model-based ones.

The traditional watermarking methods only concentrate on one distortion cannot satisfy a high security watermark. In real condition, the image distortions are various and are not expectable, for instance: JPEG compression will distort image information in high frequency part. Then the method of inserting watermark information from low frequency part to high frequency part of the image can avoid the distortion of JPEG compression. But this method is weak for cutting attack since the image will lose the information in low frequency part first. For this reason, we embed watermark in all sub-bands and it makes a watermark to have a coexisting property in part of space domain and frequency domain of protected image. We use the concept of spread spectrum to spread the watermark over sub-bands. But from the viewpoint of intellectual protection, the watermark is more important than the image, while the image quality is maintained. They did not handle the watermark. We propose an idea for enhancing the robustness of extracted watermarks. Watermark can be treated as a transmitted signal, while the destruction from attackers is regarded as a noisy distortion in channel. According to the viewpoint mentioned above, we provide an idea using ECC to detect and correct the error part of the extracted watermarks.

2. General Instructions

A binary and zero mean image is used to be the watermark shown as Fig.3. First, we decompose the original image by DWT in three levels to obtain the wavelet coefficient in each band as shown in Fig.4. If the watermarks only embedded in the high frequency subband, the information of the higher frequency will lose through the lossy manipulations such as high-pass filter. And the watermarks inserted in the high frequency subband may loss since the information of the high frequency in watermarked image is changed huge. The extracted watermark may be wrong if the watermarked image is altered with the lowpass filter or the blurring filter. In order to enhance the robustness of watermark, we embed the watermark in the middle subband after the DWT in three levels. We also adopt the properties of JND in the system.

2.1. Adaptive quantization

A simple and traditional method of the blind watermarking system is adding or subtracting a small constant in the host image. But according to HVS, human vision reacts with different sensitivity to each frequency band. In order to enhance the transparency and capacity of watermark, we adopt the property of the JND in the system. The traditional quantization table $H'_{s,o}$ with the spread spectrum method is modeled by eq(1). The watermarks lengths are adaptive based on the JND, the magnitude and the orientation of the wavelet coefficients. As a result, the watermarking system is more robust and imperceptible. Therefore, it is non-blind watermarking, and the host image is need on the detection step.

$$H'_{s,o} = I_{s,o} \times \alpha \times \left(1 + J_{s,o}\right) \qquad (1)$$

$J_{s,o}$ is the JND value at s level and o direction, and α is the weighting value. $I_{s,o}$ is the wavelet coefficient.

According to the value of the quantized coefficient in $H_{s,o}$, we classify the quatization table $H_{s,o}$ into four groups, which are part A to part D. According to Table (1), the group and the QF (quality factor) will be determined. And the adaptive quantization model is made by the magnitude of the QF as follows.

2.2. Duplicate Quantization

We adopt the cocktail watermark model [14] in our system. A duplicate quantization is modeled which contains the positive quantization and the negative quantization. The watermark is first inserted by the positive quantization, and the opposite watermark will follow the positive embedding and is embedded in host image based on the negative quantization.

If quantized coefficient is odd,

The positive quantization:

$$\begin{cases} H_{s,o} = I_{s,o} + QF - (I_{s,o} \% QF) - wm & \text{if wm} > 0 \\ H_{s,o} = I_{s,o} + QF + 1 & \text{if wm} <= 0 \end{cases}$$

The negative quantization:

$$\begin{cases} H_{s,o} = I_{s,o} + QF - (I_{s,o} \% QF) - wm & \text{if wm} <= 0 \\ H_{s,o} = I_{s,o} + QF + 1 & \text{if wm} > 0 \end{cases}$$

If quantized coefficient is even,

The negative quantization:

$$\begin{cases} H_{s,o} = I_{s,o} + QF - (I_{s,o} \% QF) - wm & \text{if wm} > 0 \\ H_{s,o} = I_{s,o} + QF + 1 & \text{if wm} <= 0 \end{cases}$$

The positive quantization:

$$\begin{cases} H_{s,o} = I_{s,o} + QF - (I_{s,o} \% QF) - wm & \text{if wm} <= 0 \\ H_{s,o} = I_{s,o} + QF + 1 & \text{if wm} > 0 \end{cases}$$

2.3. Watermark Insertion

The procedures of insertion are described as follows:

Step1. We decompose the original image Y with a three-level DWT to obtain the wavelet coefficient $I_{s,o}$ shown in Fig.4. The parameter (m,n) represent the spatial location of each pixel in the decomposed image.

Step2. Calculate the adaptive quantization table $H_{s,o}$ of each band.

Step3. We encode the watermark W using duplicate quantization algorithm.

Step4. We insert the watermark into the wavelet coefficient $I_{s,o}$ according to the order. The watermark is inserted 12 times. Six of them are based on positive quantization, and the opposite ones are based on negative ones.

Step5.Finally, we take inverse DWT of the modified wavelet coefficient to obtain watermarked image Y'.

2.4. Watermark detection

We can extract the watermark W essentially taking the inverse steps described in section 2.3. According to the detection thresholds of the different group, the watermark can be detected successfully. For watermark detection, a similarity measure CR_n is defined :

$$CR_n = 1 - \frac{\sum_{m=1}^{L} w_m \oplus w_m^*}{L}$$

$$CR = Max(CR_n) \quad \text{n=0~1}$$

L is the length of the watermark. w_m is the host watermark and w_m^* is the extracted one. n represent the different kinds of the watermark quantization table. 0 is the positive one and 1 is the negative one.

Table 1. The distributions and QF in each group

	QF	$I_{s,o}$
Part A	5	31-100
Part B	7	101-504
Part C	9	505-783
Part D	11	783-1023

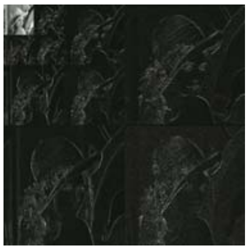

Fig.1 The decomposed Lena in three levels wavelet transform.

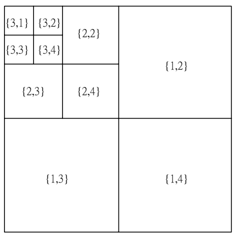

Fig.2 The order of wavelet coefficients.

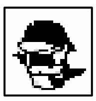

Fig.3 The inserted watermark.

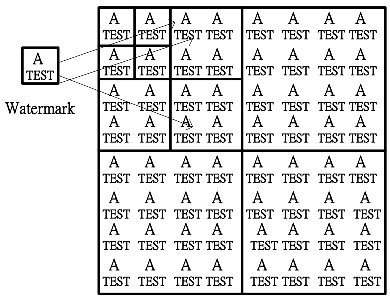

Fig.4 The order of inserting the watermark.

3. System evaluation

We use the LENA image as the test image in our experiments of which size is 256×256 in pixels. The inserted watermark size is 32*32 in pixels. The parameter α is set to 0.2.

The encoded watermark is totally 12 multiple of the original watermark. Some of them totally 6 multiple of the watermark are embedded based on the adaptive positive quantization. And the opposite 6 multiple ones based on the adaptive negative quantization will follow to encode.

3.1 PSNR of the watermarked images

We evaluate the PSNR of the watermarked test image as eq(8). Fig.5(a) shows the test image and Fig.5(b) shows the watermarked version of Fig.5(a). Table.2 tabulates the PSNR of the watermarked image with proposed algorithms. The PSNR is perfect (not smaller than 34) and the image qualities are still very well.

$$PSNR(dB) = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

$$MSE = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[f(x,y) - g(x,y)\right]^2$$

Table.2 The PSNR of watermarked images.

Image	PSNR
Pepper	40.29 dB
Lena	39.98 dB
Airplane	39.74 dB

3.2 JPEG compression

We demonstrate the JPEG compression of the watermarked images with different JPEG qualities. Fig.6 tabulates the detection responses of the watermarked images under different JPEG qualities. Even though when the JPEG qualities are smaller than 20, the responses of the watermarked image can provide a certification of the owner. In our experiments, when the JPEG quality downs to 10 or more below, the watermarked images are strictly destructed and commercially valueless.

3.3 Attacks

Robustness against geometric manipulation, such as filtering, scaling, or stirmark, is very important because these manipulations are very common and usually do not degrade too much the quality of the image. And here we present the robustness with some quite general kinds of manipulation shown as Fig.7 where the horizontal axis represents the different attack and the vertical one is the similarity. Blurring and median filtering are both altered with the 15*15 mask. And in Jitter procedure, the 60, 130, 200, 310, 440 columns are deleted, and copy the columns of 65, 190, 270, 390, 490. StirMark[21] is a generic tool developed for simple robustness testing of image marking algorithms and it simulates a re-sampling process.

Figure 5.(a) The original Lena Image

Figure 5.(b) The watermarked Lena Image

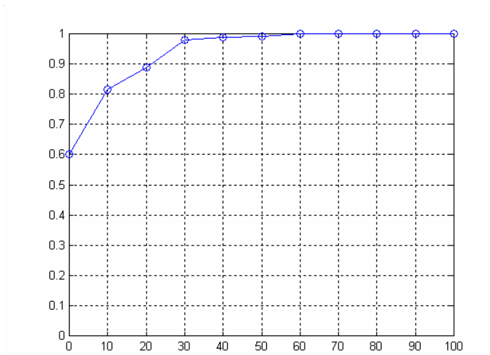

Fig.6 Detection response of the watermarked images under JPEG attacks.

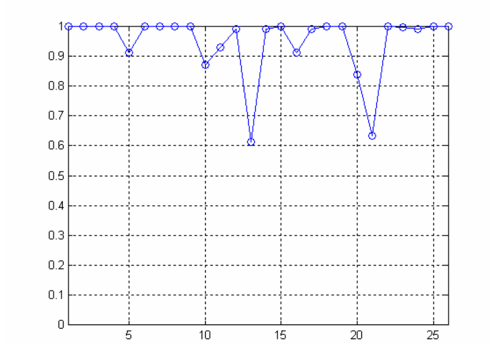

Fig.7. The similarity of the extracted watermark .

6.Conclusion

In this paper, we proposed an idea to enhance the robustness of the blind watermark. We presented a structure to satisfy the following properties of watermarking: transparency, robustness. According to the sensitivity of human perception, adaptive quantization keeps a watermarked image quality from the distortion induced by watermark-insertion methods. With the characteristic of wavelet, the watermark information is located at the spatial and frequency domain.

The robustness is maintained with the duplicate quantization. In this experiment, we demonstrated the performance of the proposed method by computer simulation. The detection response of the processed image is relatively higher.

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