A Novel Blind Watermarking Algorithm Based on Virtual Channel Technique*

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Abstract A novel blind watermarking algorithm based on virtual channel technique was proposed, by which a gray-scale image was embedded into host image. By modifying coefficients of host image in frequency domain, the host channel can be regarded as a virtual watermark channel, which was composed of several deficient sub-channels. Neither original image nor original watermark was necessary in extraction. Experimental results show that proposed algorithm provides good invisibility and robustness.

Keywords Image processing; Digital watermarking; Blind watermarking; Virtual channel

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0 Introduction

Digital watermarking embeds labels in digital content, usually for the purpose of communicating copyright and ownership information. Watermark can be embedded in spatial domain or frequency domain. Watermarking in frequency domain can distribute energy of watermark over all of host image pixels in spatial domain. That is, it provides good invisibility and robustness. As blind watermarking algorithm embedding gray-scale image can provide more copyright information and watermark can be extracted without original image, obviously it is fascinating, but it faces more challenges at the same time.

In many algorithms nowadays, gray-scale watermark is decomposed into 8 bit-planes to provide more robustness[1,2], but a large data bulk is generated at the same time even if the watermark is very small.

In this paper a novel watermarking algorithm based on virtual channel technique is proposed to embed a gray-scale image into host image. Experimental results show that this algorithm provides good invisibility and robustness to resist JPEG compression, noising, filtering and cropping, etc.

1 Watermarking algorithm

In this algorithm, after one level of 2-band DWT (discrete wavelet transform)[3~7], original image is decomposed into four sub-bands: approximate sub-band, horizontal sub-band, vertical sub-band and diagonal sub-band. Subdivide the approximate sub-band into 8×8 blocks, then transform them into DCT (discrete cosine transform) domain. The watermark is embedded into intermediate-frequency bands of 8×8 DCT blocks. Proposed watermarking system is shown in Fig. 1.

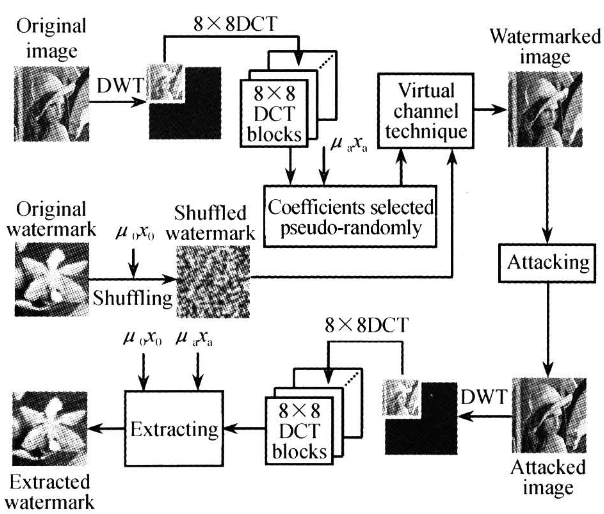

Fig. 1 Watermarking system

This algorithm is practicable for color image as well. Just as described in ref[8], host color image can be transformed from RGB color space into YC_bC_r color space, and by proposed algorithm the watermark is embedded into Y channel, which is most sensitive to human's eyes. Watermark shuffling, selecting host coefficients pseudo-randomly in transform domain and virtual channel technique are key steps, details of which are described as follows.

1.1 Watermark shuffling

Some attacks may damage completeness of watermark. In order to recover the watermark entirely and encryption, shuffle the watermark by logistic chaotic sequence, that is, eliminate correlation among watermark pixels. The key used

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in extraction is the seed of the logistic chaotic sequence. Logistic chaotic sequence is defined as follows

$$x_{n+1}=\mu x_n(1-x_n) \quad 0<x_n<1 \quad 3.6<\mu<4$$

which is sensitive to seed so that a large key-space is ensured.

1.2 Selecting host coefficients pseudo-randomly in transform domain

In every 8 × 8DCT block, m coefficients are selected pseudo-randomly at intermediate-frequency band, and every selected coefficient is correspondent to one watermark value to be embedded. The coefficients of intermediate-frequency band are shown in Fig. 2. Coefficients are selected according to following steps:

				0	10	11	25
			1	9	12	24	
		2	8	13	23		
	3	7	14	22			
4	6	15	21				
5	16	20					
17	19						
18							

Fig. 2　Coefficients in 8×8 DCT block

Step1: A logistic chaotic sequence $\boldsymbol{S}$ is generated according to key μ_a, x_a. Every element of $\boldsymbol{S}$, $\boldsymbol{S}(i)$, is used to specify m coefficients in correspondent 8 × 8DCT block. Array $\boldsymbol{A}$ is composed of all of digits following the decimal point in $\boldsymbol{S}(i)$. For example:

if　$\boldsymbol{S}(i)$ = 0.780214313320322

then　$\boldsymbol{A}$=[7,8,0,2,1,4,3,1,3,3,2,0,3,2,2]

Step2: Array $\boldsymbol{B}$ is obtained by Hash operation:

```
for  i=0 to 14
    for  j = 0 to 14
    B(15 * i+j) = mod(10 * A(i)+A(j), 26);
    end
end
```

Array $\boldsymbol{C}$ is obtained by discarding repeated elements of $\boldsymbol{B}$.

Step3: The anterior m elements of $\boldsymbol{C}$ are corresponding to m coefficients in one 8 × 8 DCT block. Thus, m coefficients are selected pseudo-randomly as host coefficients.

When host coefficients are specified by algorithm itself rather than pseudo-random means, attackers will attack watermarked coefficients only instead of the whole image, and then host image will not be distorted very much even if the coefficients are attacked vehemently. Such attack is so high-performance and the effects can be imaged. In this algorithm, host coefficients are selected pseudo-randomly to avoid attacking watermarked coefficients directly.

1.3 Virtual channel technique

Watermarking technique can be described as follows: host image and watermark are transmitted through host channel simultaneously. Virtual channel technique is shown in Fig. 3. Here, host channel, C^V, is composed of selected coefficients of host image in frequency domain. Channel C^*, which has the same width as C^V, is divided into N sub-channels: C_0^w, C_1^w, C_{-1}^w, C_2^w, C_{-2}^w ··· To avoid confusing of adjacent sub-channels, isolation region

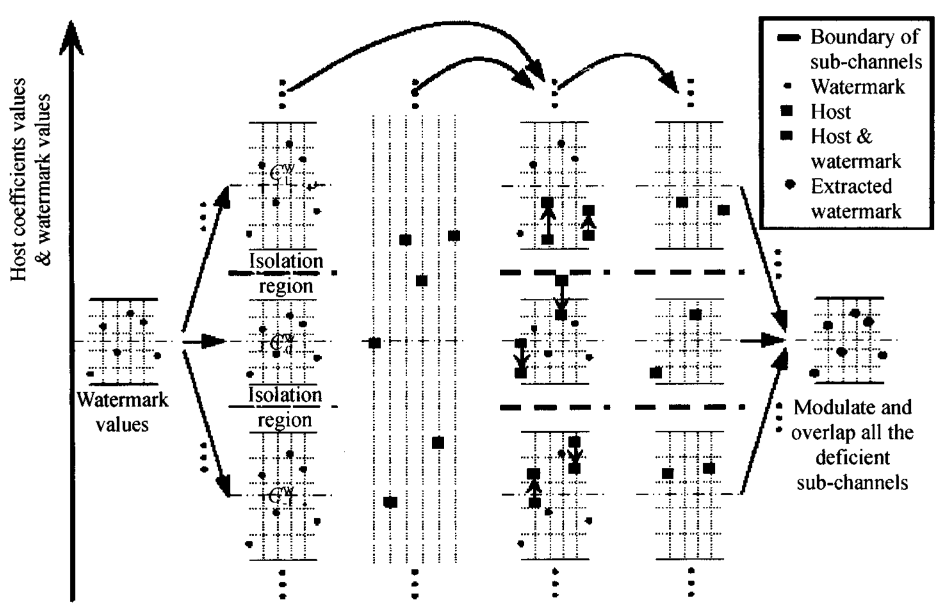

Fig. 3　Virtual channel technique
The farther the distance to sub-channel C_0^w is, the wider the sub-channel is

is set. Shuffled watermark is modulated and added into every sub-channel so that every sub-channel gets entire reflection of the watermark. The farther the distance to sub-channel C_0^w is, the wider the sub-channel is. Strength of watermarking is adjusted by adjusting the width of sub-channels.

Modify host coefficients : Consider $V(i)$ and $W(i)$, $W(i)$ is a watermark value, and $V(i)$ is host coefficient correspondent to $W(i)$. $W(i)$ is modulated into N sub-channels, whose reflection values are: $W_0(i), W_1(i), W_{-1}(i), W_2(i), \cdots V(i)$ is replaced by the nearest watermark reflection value. D is defined to evaluate the distance between host coefficient $V(i)$ and watermark reflection value $W_n(i)$

$$D=\frac{|V(i)-W_n(i)|}{\sqrt{|V^2(i)-W_n^2(i)|}},$$

$$V(i)\cdot W_n(i)\neq 0,\ V^2(i)\neq W_n^2(i)$$

After having been modulated, data transmitted through watermarked host channel have double meaning: They are DCT coefficients of host image with small perturbation, when considered from standpoint of host channel;on the other hand, they are reflection values of watermark pixels, which may be from disparate sub-channels, when considered from standpoint of watermark sub-channels.

Virtual channel: Considering the watermarked host coefficients, they are regarded as watermarked host channel. At the same time these coefficients can be regarded as a watermark channel, which is composed of N deficient watermark sub-channels. Modulating and overlapping these N deficient sub-channels an entire watermark channel is obtained. Thus, we regard watermarked host channel as a virtual channel of watermark.

In extraction, watermarked host channel is interpreted as watermark virtual channel. Boundary of adjacent sub-channels is defined as midline of isolation region. Modulating and overlapping the N deficient watermark sub-channels entire watermark information can be obtained.

In many blind watermarking algorithms[8~10], watermarking strength is determined by a constant and has no concern with frequency coefficients, so it is impossible for these algorithms to take full advantage of the host image′s psycho visual redundancy. In algorithm, watermarking strength is adjusted by frequency coefficients through virtual channel technique to make up above-mentioned deficiency. This makes algorithm more robust.

2 Experimental results and analysis

The algorithm has been simulated on MATLAB6. 5. Several different host images and watermarks are tested and good results are obtained. Robustness of this algorithm is illustrated by one of our experiments. The host image is the well known test image Lena(512×512×8bit). A flower image (64×64×8bit) is used as watermark. PSNR(Peak Signal to Noise Ratio) is used to quantify degradation of host images and extracted watermarks.

Original image and watermarked image are shown in Fig. 4. PSNR of the latter is 40. 5809 dB. The watermarked image remains high quality, from which entire watermark can be extracted (Fig. 5. B). PSNR values of experiment are given in Table. 1. Watermarks extracted from watermarked host images after various attacks are shown in Fig. 5. Under the same condition, our algorithm provides better robustness against JPEG compression attacks than algorithm[1], and is 2. 8 times the watermark capacity of the latter′s. Comparing our algorithm with algorithm[9]: They are much the same robust against JPEG compression attacks, but

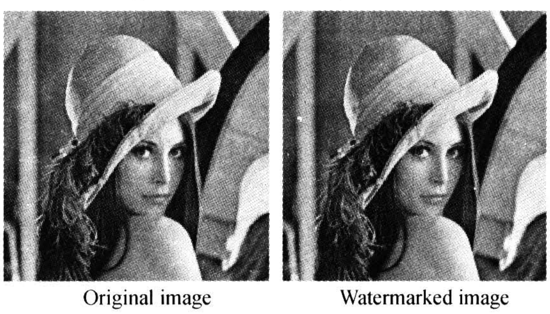

Fig. 4 Original image and watermarked image

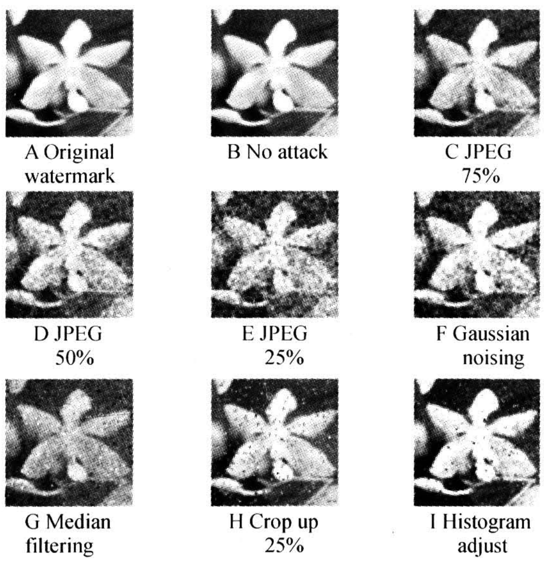

Fig. 5 Watermarks extracted from watermarked host images after various attacks

Table. 1 PSNR values of image degradation dB

Attacks	Host PSNR	Watermark PSNR
B No attack	40.5809	38.6947
C JPEG 75%	32.4421	22.7419
D JPEG 50%	31.4563	19.5091
E JPEG 25%	30.4805	15.6454
F Gaussian noise	29.5013	17.9194
G Median filtering(3×3)	32.9979	18.3279
H Crop up 25%	11.3117	29.7634
I Histogram adjust	19.9636	18.2914

our algorithm embeds a gray-scale image as watermark which carries further more information than the latter's. From above data and comparison with earlier algorithms, it can be concluded that our algorithm not only can realize blind extraction, but also provides high watermark capacity, good invisibility and robustness.

3 Conclusions

Virtual channel technique is proposed in this paper, based on which a blind watermarking algorithm is proposed. By modifying coefficients of host image in frequency domain, data transmitted though host channel can be regarded as both host image coefficients and watermark reflection values. Thus, there seems to be a virtual watermark channel in watermarked host image, which is composed of several deficient sub-channels. An entire watermark channel can be obtained after modulating and overlapping these deficient sub-channels. Neither original host image nor original watermark is necessary in extraction. Experimental results demonstrate that the proposed algorithm has good robustness.

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基于虚拟通道技术的数字图像灰度水印算法

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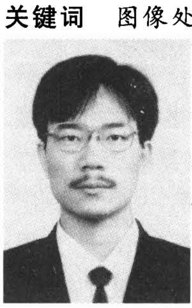
摘 要 根据提出的虚拟通道技术,提出一种在载体中嵌入灰度图像作为水印的数字水印算法.通过修改载体频率域系数,载体通道可被看成一个虚拟的水印通道,它由若干个缺损的水印子通道构成,水印的提取不需要原始载体或原始水印的参与.实验结果表明提出的算法很好地保证了水印的不可见性和稳健性.

关键词 图像处理;数字水印;盲水印;虚拟通道



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