Digital Watermarking Algorithm based on Gauss Pyramid Decomposition

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Abstract: In this paper, the watermark information is embedded and extracted in the discrete cosine transform domain, and the spread spectrum binary codes of the watermark image after the Gauss Pyramid decomposition is adaptively embedded in the middle frequency component near the low frequency. The experiment proves that the algorithm is simple and easy to be realized. It has strong robustness and better invisibility for the image processing of JPEG compression and clipping.

Keywords: Spread spectrum; Gauss Pyramid decomposition; Discrete cosine transform; Digital watermarkin g

1. Introduction

With the development of digital technology, the application of Internet is more and more widely. Digital watermarking technology plays a major role in the copyright protection of digital media. Digital watermarking technology is information hiding technology. Its basic idea is to embed secret information in digital images, audio, video and other digital products in order to protect the copyright of digital products, prove the authenticity of the product, and track the piracy or to provide additional information of the production. Watermark can be digital, serial number, text, image logo and other information.

Watermark robustness, security and invisibility are the basic characteristics of digital image watermarking, but the robustness and invisibility are a pair of contradictory factors. Generally speaking, the greater the amount of information causes the stronger the robustness, but a worse the invisibility affects a larger the watermark image, it will affect the robustness if it is not handled. In this paper, the watermark image is decomposed in multi-resolution, and there are many ways to decompose the image. The most commonly used is the multi-resolution decomposition method based on the wavelet transform. However, the multi-resolution product generated by this method is not suitable as the digital watermark information. Therefore, Gauss Pyramid resolution is proposed to reduce the watermark image.

The application of spread spectrum technology to digital image watermarking technology can significantly enhance the robustness and security of the system. The spread spectrum technology can be regarded as a bandwidth exchange signal to noise ratio: the signal energy is extended to a wide band, and a very low signal to noise ratio is obtained, which makes it difficult to detect, explain or interfere with the signal. Although the total signal power may be very large, the signal to noise ratio in any frequency band is very small, which makes it difficult to detect the signal to get the spread of the spectrum, which means the hidden information is difficult to be detected. The direct sequence spread spectrum (DSSS) used in this paper is a common spread spectrum technology. The pseudo-random sequence is used as the coding sequence, and the Gold sequence is used as the spread spectrum code.

1.1. Image of Gauss Pyramid decomposition

Definition: the image is the zeroth layer of Gauss Pyramid, and the multi-resolution reduction form is the first layer of Gauss Pyramid. The pixel gray value of the layer image is calculated by the weighted average of the pixel gray value of the 55 window in the -1 layer image.

$$G_l = \sum_{m=-2}^{2}\sum_{n=-2}^{2}\omega(m,n)G_{l-1}(2\times i+m, 2\times j+n) \quad (1)$$

where $0<l<N, 0\le i<C_l, 0\le j<R_l, N$ is the total number of layers of Gauss Pyramid, C_l and R_l represents the horizontal width and vertical height of the first l level image of Gauss structure in Pyramid, respectively, and $C_l = C_{l-1}/2, R_l = R_{l-1}/2$. The weights are defined as follows:

$$\begin{cases} \omega(m,n) = \hat{\omega}(m)\hat{\omega}(n) \\ \sum_{m=-2}^{2}\hat{\omega}(m) = 1 \\ \hat{\omega}(0) = \alpha \\ \hat{\omega}(-1)\hat{\omega}(1) = 1/4 \\ \hat{\omega}(-2)\hat{\omega}(2) = 1/4 - \alpha/2 \end{cases} \quad (2)$$

The formula α is a constant, and $\alpha = 0.8$ in this paper. Because the first l level image of Gauss Pyramid structure is the weighted average of the previous layer, the first l level image contains the low frequency information of the previous layer. The gray level adaptive watermark image is $\frac{N}{2^l} \times \frac{N}{2^l}$ decomposed into the first l level image.

1.2. Gold Codes

The excellent characteristics of the spread spectrum system are closely related to the design of the spread spectrum code. Therefore, the spread code with good pseudo random characteristics and related characteristics is very important for the application of spread spectrum technology. The generation of Gold codes is based on the m sequence, and the m sequence is a pseudo random sequence of N = 2 n -1 generated by the N binary linear feedback shift register. Its elements are composed of 1 and 0, with equilibrium and excellent autocorrelation characteristics. For m sequences, few sequence sets can be made up of small cross correlation values, and Gold codes are composed of two codes, such as two code long phases, and the same code clock rate of the same sequence (two m sequences with very small cross values). A new Gold code can be obtained by changing the relative displacement of the two m sequences. Gold codes retain the excellent characteristics of m sequences, and their autocorrelation features are similar to the m sequences, and the correlation values do not exceed the maximum intercorrelation values between the original m sequences, so the independent code groups with much more than the m sequences can be obtained, which makes the Gold code widely used in multiple access techniques. If the number of "1" symbols in the Gold code is only one more than the "0" symbol, that is to balance the Gold code. When choosing Gold code as spread spectrum code, we should use balanced code.

2 Detailed algorithm

2.1. Watermark generation

The watermark image is decomposed by Gauss Pyramid in the formula (1). The watermark image (32 x 32) is decomposed and the original information is obtained by two values. Then the watermark signal is spread by direct sequence spread spectrum technology, and the Ch IP rate of cr=16 is used to repeat the watermark signal s [J]. (over sampling) to form a modulation signal:

$$\begin{cases} c[k] = s[k] \\ (j-1)\cdot cr + 1 \le k \le j \cdot cr \end{cases} \quad (3)$$

Finally, the Gold code is used to spread spectrum modulation to generate the spread spectrum watermark signal.

$$w[k] = Ec[k]g[k] \quad (4)$$

The signal gain is used to control the tradeoff balance between the robustness and invisibility of the watermark. The greater the e , the stronger the robustness and the worse the invisibility, and vice versa.

2.2. Watermark embedding

Compared with the spatio-temporal image watermarking, the watermarking embedding algorithm in the transform domain has many advantages, in which DCT has good energy compression and correlation ability, and is compatible with the common image compression standard JPEG, so it has received extensive attention. In this paper, the watermark embedding is selected in the DCT domain. First, the original image I is divided into K non overlapping 8 * 8 sub blocks.

$$I = \bigcup_{K=0}^{K-1} I_K(u,v), \qquad 0 \le u,v < 8 \quad (5)$$

Then the DCT transformation is carried out for each block

$$\tilde{I}_K = DCT[I_K(u,v)] \quad (6)$$

Each DCT transform coefficient is sorted by the word form (Table 1). (for the size of the 8 x 8 DCT transform coefficient block, it should be transformed from a two-dimensional description into a one-dimensional description) to embed the watermark sequence into the middle frequency coefficients near the low frequency. This is because the most sensitive part of the human eye is the low frequency coefficient corresponding to the DCT transform, so the low frequency coefficient should be retained as far as possible, and the JPEG lossy compression will be discarded the high frequency part, and in view of this, it is most appropriate to adopt the middle frequency coefficient position near the low frequency. In this paper, the 32 * 32 watermark image is extended by 16 bits, and then modulated with GOLD code. The modulation sequence is grouped by every 16 bits and is embedded into the ninth to 24 (Table 1 blackbody) components of each 8 * 8 DCT transform block. And then reverse the font arrangement to the IDCT transform.

$$\tilde{I}' = \bigcup_{K=0}^{K-1} IDCT[\tilde{I}'_K(u,v)] \quad (7)$$

The image embedded in the watermark is obtained.

2.3. Watermark extraction

First, 8*8 DCT transform is carried out for the original image and the watermark image, respectively. The spread sequence of the watermark information is extracted according to the embedded position (9 to 24), respectively.

$$W'_S = \bigcup_{k=0}^{k-1} \left\{ [\tilde{I}'_K(u) - I_K(u)] / E \right\} \quad (8)$$

The Gold code is generated according to the same key, and then the two value sequence of the watermark image is extracted according to the reverse operation of the extended spectrum. In this way, the watermark sequence is demodulated and the watermark image W ' is rebuilt.

3. Experimental result

In the simulation experiment, the original image is 512 * 512 Lena gray scale test images. The watermark image is decomposed by Gauss to 32 * 32 two value images. The original image, the watermark image and the watermark carrier image are given in Figure 1. Table 1 shows the experimental data for image processing, where SC is the similarity between the original watermark and the structure.

$$SC = \frac{\langle WW' \rangle}{\|W\|^2} \tag{9}$$

W is the original watermark, W 'is the extracted watermark, and r is the correlation coefficient. PSNR (Peak Signal - to-Noise Ratio) peak signal to noise ratio (peak signal to noise ratio), this algorithm is not subjected to the attack test before the watermark carrier image and the original image of the PSNR is 34.9855, the table is given the attack test image and the original carrier image PSNR, the targeted interference modulation signal gain E, better performance of anti attack performance. To achieve the best results of invisibility and robustness.
Experimental results:

(a) Original Lena image

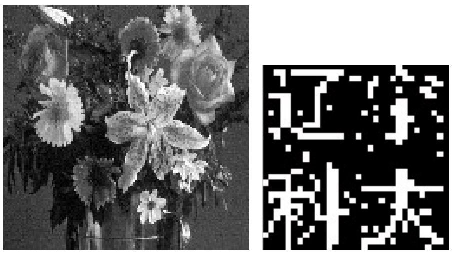
(b) The watermark image after Gauss decomposition

(c) Watermarked Lena image

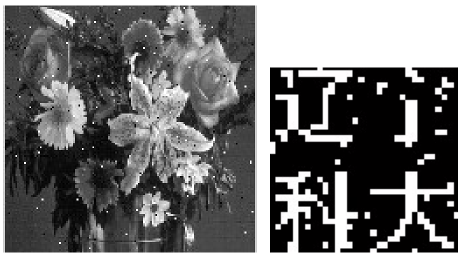
Figure 1. Original image

Table 1. Experimental Data for Image Processing

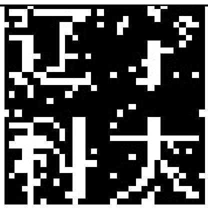
Image processing method	SC	r(Relevance)	PSNR
JPEG compression	0.9564	0.8879	33.6682
Q=30	1	1	31.3584
Q=40	1	1	33.1573
Q=50	0.8641	0.7333	22.1653
Salt and pepper noise (0.02)	1	0.9678	18.1409
Histogram equalization	0.8231	0.7568	245.9883
Multiplicative noise (0.01)	0.9676	0.9875	23.9893
Lower contrast	0.9326	0.7766	15.3692
[0.2 0.8]	0.9706	0.9865	14.2358
Increase the contrast [0.3 0.7]	0.9706	0.9878	13.5860
Darkening of images [0 0.6]	0.8976	0.7794	34.4365
Image brightening [0.4 1]	0.9365	0.6681	28.6897
median filtering	0.9875	0.7830	26.8530
3 degrees of image rotation Gaussian noise (0.005)			



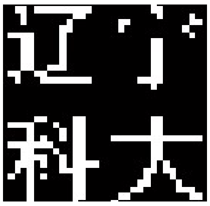
JPEG compression Q=30



Salt and pepper noise 0.02



Multiplicative noise 0.01



Histogram equalization

Increase the contrast [0.3 0.7]

Lower contrast [0.2 0.8]

Figure 2. Watermark image extracted after processing

4. Conclusions

In this paper, a watermark generation method based on the method of image Gauss decomposition and spread spectrum technology is proposed. The watermark is embedded in the frequency domain by using DCT transform. The experiment shows that the quality of the generated watermark image is good, it has good robustness to the general image processing, and the scheme has some improvements, especially in the detection algorithm of the watermark. The detection needs the original image, which may bring inconvenience in the practical application, and the direct correlation and threshold determination simplified detection methods can be considered.

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