Improved multiple watermarking algorithm for Medical Images

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Muhammad Usman shoukat
School of Automation and Information
Sichuan University of Science and Engineering, Yibin 644000, china
Artificial Intelligence Key Laboratory of Sichuan province, Sichuan University of Science and Engineering, yibin 644000, china
usmanryk12@gmail.com

Yang Yiqiang*
School of Automation and Information
Sichuan University of Science and Engineering, Yibin 644000, china
Artificial Intelligence Key Laboratory of Sichuan province, Sichuan University of Science and Engineering, yibin 644000, china
yqyang_1992@126.com
*Corresponding author

Saqib Ali Nawaz
College of Information Science and Technology, Hainan University, Haikou, China 570228
saqibsial20@gmail.com

Uzair Aslam Bhatti
School of Geography (Remote Sensing Lab), Nanjing Normal University
uzairaslambtti@hotmail.com

Anum Mehmood
School of Medicine, Southeast University, Nanjing Jiangsu China
gooddranam@yahoo.com

Raza Ahmad
College of Information Science and Technology, Hainan University, Haikou, China 570228
wenbo1147@yahoo.com

ABSTRACT
At present, most watermarking algorithms use linear correlation method to detect watermarks. However, when the original media signal does not obey the Gaussian distribution, or the watermark is not embedded into the media object to be protected, this method has certain problems. The imperceptibility constraint of digital watermark determines that watermark detection is a weak signal detection problem. Using this feature, firstly, based on the statistical characteristics of DCT (discrete cosine transform) and DWT (discrete wavelet transform), the generalized Gaussian distribution is used to establish its statistical distribution model. Then, the watermark detection problem is transformed into a binary hypothesis test problem. The basic theory of weak signal detection in non-Gaussian noise is used as the theoretical detection model of multiplication watermarking, and the optimized multiply embedded watermark detection algorithm is derived. The algorithm is tested. The results show that the proposed watermark detector has good detection performance for the blind detection of watermarking with unknown embedding strength. Therefore, the detector can be applied in the copyright protection of digital media data.

CCS Concepts
• Security and privacy→ Security services→ Digital rights managemen→Security and privacy→Software and application security→ Software security engineering

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Keywords
Discrete Cosine Transform (DCT); feature extraction; Multiplicative watermarking

1. INTRODUCTION
With the rapid development of multimedia technology and computer network technology, the copyright protection of digital media has become more and more prominent. As a new way of digital copyright protection, digital watermarking technology has attracted people's attention in recent years and has become A current research hotspot.

Digital watermarking technology can be understood as a form of communication, in which the original media data is regarded as a kind of noise, and the watermark is the signal to be transmitted [1]. Based on the assumption of the additive white Gaussian noise channel (AWGN) model, many Scholars use linear correlation methods to detect watermarks [2]. However, the linear correlation watermark detection method has the following problems: First, the existing watermarking algorithms can be basically divided into time/space domain methods and transform domain methods. Two major categories, however, whether it is time/space or transform domain, statistical modeling of the carrier image with Gaussian distribution is not suitable [3−6]. Second, the watermark signal can be either embedded or passed. The non-embedded strategy is embedded in the original media data. According to the basic theory of signal detection, the watermark detector designed by linear correlation method is not optimized for any of the above cases [7-10].

A typical DCT digital watermark processing flow includes original image DCT transform, watermark binary sequence, watermark embedding, and extraction, as shown in Fig 1.

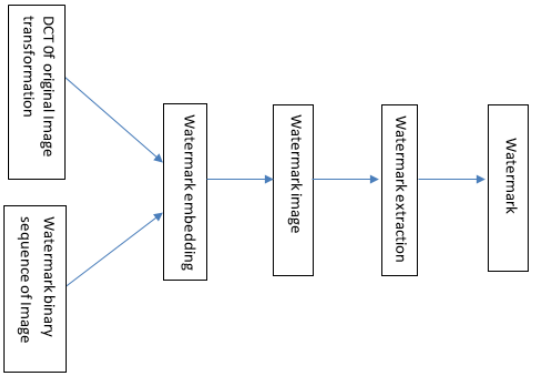

Figure 1. Basic workflow of DCT watermarking

Because the watermark multiplication and embedding method can make full use of human perceptual masking characteristics, and the content is self-applicable, it can better satisfy the watermark imperceptible characteristics. Therefore, the watermark multiplication embedding mode has a good application prospect. However, the current multiplication The research on embedding watermark is still less. Imperceptibility is a basic feature of digital watermarking, which determines that the detection of watermark signal is a weak signal detection problem. This paper focuses on blind image watermarking technology in discrete cosine transform (DCT) domain. The research is carried out, and the basic principles of statistical inference theory and weak signal detection are applied. A robust detection algorithm based on watermarking is proposed.

Section 1 of this paper presents a multiply-embedded watermark detection algorithm. Section 2 introduces the implementation of the DCT domain digital watermark detector. Section 3 gives the Monte Carlo results of the detector's detection performance. Finally, the conclusion is presented with future work in last section.

2. FUNDAMENTAL THEORY

According to the research results in [8], we embed the watermark information on the intermediate frequency DCT transform coefficients to obtain better results of the watermark in both robustness and imperceptibility. The watermark is embedded into the original media data by multiplication and embedding. Among the DCT transform coefficients, the original coefficient to be modified is directly proportional to the size of the coefficient itself. The embedding rules are as follows:

$$y_{i} = (1 + \alpha w_i)x_i, \qquad i = 1, \dots, N \qquad (1)$$

$$H_0: y_i = x_i, \qquad i = 1, \dots, N \qquad (2)$$
$$H_1: y_i = x_i(1 + \alpha w_i), \qquad i = 1, \dots, N$$

Suppose the probability density function of the DCT coefficient is expressed as $p_x(x_i)$, so in the H_0 suppose, y_i the probability density function is

$$p_{yi}(y_i; H_0) = p_x(y_i) \qquad (3)$$

Suppose, since the watermark is a weak signal, it does not change the properties of the original coefficient, so, $|1 + \alpha w_i|$ <1, multiply embedded rules by watermark know, y_i the probability density function is [11]

$$p_{yi}(y_i; \alpha, H_0) = \frac{1}{|1+\alpha w_i|} p_x\left(\frac{y_i}{1+\alpha w_i}\right) = \frac{1}{1+\alpha w_i} p_x\left(\frac{y_i}{1+\alpha w_i}\right) \qquad (4)$$

The research results in the field of image compression and coding show that the AC coefficient of the image DCT is subject to the general Gaussian distribution after the transformation, and the probability density function has the following form [4]:

$$p_x(x) = Ae^{-|\beta x|^c} \qquad (5)$$

Where $\beta = \frac{1}{\sigma}\left(\frac{\Gamma(3/c)}{\Gamma(1/c)}\right)^{1/2}$, $A = \frac{\beta c}{2\Gamma(1/c)}$, σ is the standard deviation of the coefficient, c is the shape parameter, $\Gamma(.)$ For the Gamma function. DCT transformation is the optimal Transformation, as assumed by the literature [8], where the DCT coefficient is statistically independent, the combined probability density function of N the dimensional observation sample vector is Y a single sample, y_i the product of the probability density, and therefore in the $H_1$and H_0 the combined probability density of the two hypotheses is respectively.

$$p_Y(Y; H_0) = \prod_{i=1}^{N} Ae^{-|\beta y_i|^c} \qquad (6)$$

$$p_Y(Y; \alpha, H_0) = \prod_{i=1}^{N} \frac{A}{1+\alpha m_i} e^{-\left|\frac{\beta y_i}{1+\alpha m_i}\right|^c} \qquad (7)$$

Therefore, under the two assumptions, their ratio is

$$l(Y) = In\frac{p_Y(Y;\alpha,H_1)}{p_Y(Y;H_0)} = Inp_Y(Y;\alpha,H_1) - Inp_Y(Y;H_0) \qquad (8)$$

As can be seen from the formula (2), for unknown embedding strength α, H_0 and H_1 The two assumptions correspond to each other $\alpha = 0$ and $\alpha \neq 0$. Due to the imperceptible constraint of watermark, embedded strength α generally small, will $Inp_Y(Y; \alpha, H_1)$ in $\alpha = 0$ at the first-order Taylor stakes, the nod is like

It's compared to

$$l(y) = \left.\frac{\partial Inp_Y(Y;\alpha,H_1)}{\partial \alpha}\right|_{\alpha=0} .\alpha \qquad (9)$$

All material on each page should fit within a rectangle of 18 × 23.5 cm (7" × 9.25"), centered on the page, beginning 1.9 cm (0.75") from the top of the page and ending with 2.54 cm (1") from the bottom. The right and left margins should be 1.9 cm (.75").

3. WATERMARK DETECTOR IMPLEMENTATION

3.1 Estimation of Probability Density Function of DCT AC Coefficient

The estimation of the generalized Gaussian density function of the image DCT coefficient is the basis of the watermark detector design based on statistical inference method in the DCT domain. It can be seen from equation (5) that its probability density function is completely determined by σ and for a specific image. In order to obtain the probability density function of the DCT AC coefficient, we estimate the parameter σ sum by using the minimum relative entropy estimation method proposed in [12]. First, the value range of the DCT AC coefficient is divided into equal intervals. The interval, the frequency of the coefficient in each different interval is calculated, and normalized to $h_k(k = 1,2, \dots, n)$, the frequency histogram of the coefficient is obtained. Then the shape parameter and the standard deviation are respectively and cnknk,..., 2,1 = ic i σ The generalized probability density function is discretized, and the integral of the probability density function over the interval corresponding to the frequency histogram is calculated $F_x(C_n)$, The relative entropy between the discrete model of the generalized Gaussian distribution and the coefficient histogram is

$$\Delta H(\sigma_i, C_c) = -\sum_{k=1}^{N} h_k \log\frac{F_x(C_n)}{h_k} \qquad (10)$$

The smaller $\Delta H(\sigma_i, C_i)$, C_i and σ_i the closer the generalized Gaussian probability density function of the parameter is to the actual probability density function of the coefficient. Therefore, choose Make $\Delta H(\sigma_i, C_i)$ The minimum generalized Gaussian probability density function is used as the probability density function of the DCT AC coefficient. The 8×8 pixel DCT transform is performed on the gray image Camera man and Fishing boat in the standard image library, and the DCT coefficient is minimized by the relative entropy method.

4. EXPERIMENTAL RESULTS AND ANALYSIS

Image of abdomen 512 X 512 is used to embed watermark as our proposed research is basically based on medical image analysis and beneficial for health industry [10-16]. Fig. 2 shows the detail about image and watermark embedding method.

Figure 2. Original medical image and watermark

In this paper, the NC (normalized correlation coefficient) value is used to compare the similitude between the original watermark image and the extracted watermark image to evaluate the strength of the algorithm. The higher the NC value, the better the watermark similarity and the stronger the strength of the algorithm. The second part of the experiment verifies the effect of the algorithm tampering by adding different tampering attacks to different vector images.

4.1 Conventional Attacks

The performance of the proposed algorithm is tested against the different conventional attacks.

Table 1. PSNR and NC under Conventional Attacks based on DCT and DWT.

Conventional attacks	Gaussian noise			JPEG Compression		
	2%	4%	8%	20%	30%	40%
PSNR (db)	15.82	14.21	13.09	33.52	37.37	39.6
NC	0.85	0.9	0.9	0.81	0.86	0.9

The Table 1 shows that proposed algorithm NC value is high in different conventional attacks and thus its robust against these attacks.

4.2 Geometric Attacks

The geometric attack's robustness always has been a problem. The algorithm tests a series of Geometric attacks. Table 2 shows the performance of algorithm against different attacks. Rotation clockwise upto 30ºf is giving the satisfactory result. However, scaling attack results of NC value is bit less but acceptable because of better results in clipping and translation attacks.

Table 2. PSNR and NC under Geometric Attacks based on DCT with DWT.

Geometric Attacks	Attack strength	PSNR (dB)	NC
Rotation (clockwise)	10º	17.82	0.91
	20º	16.75	0.85
	30º	16.13	0.95
Rotation (Anticlockwise)	10º	14.14	0.90
	30º	14.84	0.81
	40º	14.16	0.94
Scaling	×0.4	-	0.73
	×0.8	-	0.81
Translation (Left)	10%	15.50	0.90
	15%	12.04	0.82
	30%	11.67	0.81
Translation (down)	10%	15.87	1
	25%	13.55	1
	40%	12.45	0.95
Clipping (Y direction)	20%	-	0.90
	30%	-	0.90
Clipping (X direction)	10%	-	0.90
	30%	-	0.85

Comparison with other Algorithms. Table 3 shows the robustness of the proposed algorithm against geometric attacks as well as conventional attacks after comparison with individual approaches DCT and DWT. The robustness of the watermarking algorithm optimized by rotation correction against the rotary attack is better than that of the watermarking algorithm.

Table 3. Comparison of the three algorithms

Attacks strength	PSNR (db)			NC		
	DWT	DCT	DWT-DCT	DWT	DCT	DCT-DWT
Rotation 10º (Clockwise)	17.82	17.82	17.82	0.73	0.42	0.91
Rotation 40º (Anticlockwise)	14.16	14.16	14.16	0.75	0.74	0.94
Scaling(×0.8)	-	-	-	0.38	0.75	0.81
Translation 10%（left）	15.50	15.50	15.50	0.83	0.30	0.90

Translation 10%(down)	15.87	15.87	15.87	0.52	0.63	1
Cropping 10% (X axis)	-	-	-	0.92	0.62	0.90
Cropping 20% (Y axis)	-	-	-	0.92	0.74	0.90
JPEG Compression (40%)	39.60	39.60	39.60	0.80	0.85	0.90
Gaussian noise (4%)	14.21	14.21	14.21	0.43	0.74	0.90

In last, Fig. 3 shows the impact of different types of attack on image before and after the restoration of watermark from the medical image.

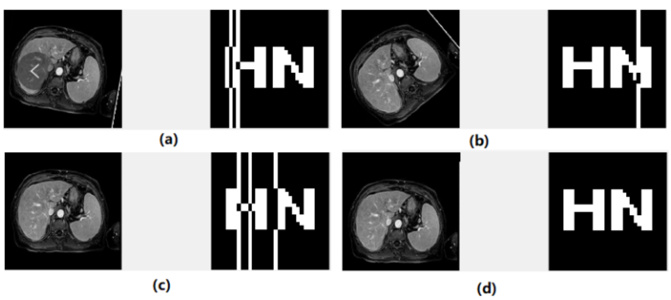

Figure 3. Different attacks impact on the image after watermark restoration (a) Clockwise rotation 10% (b) Anti-Clockwise rotation 10% (c) Scaling attack 0.8 (d) Translation Down 10%

5. CONCLUSION

In this paper, the existing problems of watermark detection methods are studied, and a DCT transform domain multiplication embedded image watermark detection method is proposed. Because the blind image watermark has no original image as reference when it is detected, this paper regards the original image as one. For this reason, the statistical inference theory is applied to transform the watermark detection problem into a binary hypothesis test problem. Based on the generalized Gaussian distribution model of DCT AC coefficients, the basic principle of weak signal detection is used to propose the corresponding multiplication embedding.

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