A Novel Robust Color Image Digital Watermarking Algorithm Based on Discrete Cosine Transform

Tai-yue Wang
1. School of Mathematics and Physics, China University of Geosciences, Wuhan 430074, P. R China
2. School of Mathematics and Statistics, South Central University for Nationalities, Wuhan 435003, P. R China
wangty6895@126.com

* Hong-wei Li
School of Mathematics and Physics, China University of Geosciences, Wuhan 430074, P. R China
hwli@cug.edu.cn

***Abstract*—Digital watermarking technology is a very good method for protecting copyright. In this paper, in terms of requisition of imperceptibility and robustness of watermarking, the coefficient features of Discrete Cosine Transform (DCT) are introduced and a new image watermarking scheme based on Discrete Cosine Transform is proposed. Digital watermark is embedded in original image by subtle perturbations of Discrete Cosine Transform corresponding coefficients. Experimental results show that the proposed watermarking scheme is feasible and simple, the embedded watermarking images have little difference with the original images and the extracted watermark is accurate. Moreover, it is imperceptible and robust against various signals processing such as noise adding, cropping, rotating and sharp, etc.**

***Index Terms*—digital watermarking, Discrete Cosine Transform, watermarking algorithm, robustness, evaluation index**

I. INTRODUCTION

With the development of multimedia technology and network communication technologies, digital products are growing popularity. However, digital products can easily be illegally copied and tampered with. Traditional encryption technology alone has been insufficient to address the legitimate right. Characterized by a specific digital signage, hidden digital watermarking in digital products is able to play a major role.

According to the watermark embedding technology, the digital watermark is divided into spatial domain and transform domain[1]. Change the amplitude of the signal sampling points known as airspace watermark; change the coefficients of the transform domain known as transform watermark.

The added a digital watermark must have the following Characteristics[2,3]: (a)Imperceptibility. The added digital watermark information should not cause obvious visual difference of the product. And hidden information is not easily or can not be aware of. (b) Robustness. The digital watermark information can be extracted after the transformationor processing.(c)Information maximization. Embedding digital watermark information into digital products as much as possible. (d) Certainty. Copyright information of the digital watermark should be able to uniquely determine the owner of the digital product. Generally, transform domain algorithms can embed large amount of digital watermark information, and other advantage of digital watermark is imperceptibility, robustness, security. In this paper, the digital watermark is a transform domain algorithm, and the texture complexity[4] and edge feature[5] of the carried image is not considered. The color image is divided into block first, and then digital watermark is embedded in original image by subtle perturbations of corresponding coefficients of DCT, finally the digital watermark information is extracted after different attacks.

II. DISCRETE COSINE TRANSFORM

DCT the orthogonal transformation method, proposed by Ahmed, etc. in 1974. The real part of the Fourier transform has many advantages, such as a high compression ratio, a small bit error rate, concentrate information and low computational complexity. The basic principle of DCT is that the image is first divided into $M \times N$ sub-blocks, and then perform two dimensional DCT for each sub-block separately. The $M \times N$ sub-blocks coefficients constitute coefficient matrix. The coefficient matrix is formed according to the Zig-Zag order. The upper-left corner of the first element is direct current(DC), known as the DC coefficient which represents the average gray level of the current data block. Following the DC coefficient is the low frequency coefficients. The lowest right corner corresponds to the most high frequency coefficient, which is alternating

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current(AC) component of data block, called the AC coefficients After DCT, a series of image sub-blocks can be obtained to reconstruct image. The transform coefficients of image are almost unchanged after transformation. Channel error, quantization error and random noise are distributed to each pixel after reconstruct image. These errors will not be accumulated. $M \times N$ is usually taken to be 8×8 or 16×16 . The formula of DCT and inverse DCT is as follows [6, 7]:

$$F(u,v)=\frac{2}{\sqrt{MN}}c(u)c(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N} \quad (1)$$

$$f(x,y)=\frac{2}{\sqrt{MN}}c(u)c(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}F(u,v)\cos\frac{(2x+1)u\pi}{2M}\cos\frac{(2y+1)v\pi}{2N} \quad (2)$$

where $c(w)=\begin{cases}\frac{1}{\sqrt{2}} & u,v=0\\ 1 & others\end{cases}$.

III. EMBED AND EEXTRACT WATERMARKS OF DCT

3.1 Watermark Algorithm and Evaluation Criteria

Let the original image be *I*, which size is $M_1 \times M_2 \times 3$ and let the watermark image be *W*, which size is $N_1 \times N_2 \times 3$ .And $M_1 \times M_2 \times 3 = N_1 \times N_2 \times 3 \times 8 \times 8$. First divided the original image into 8×8 sub-block to obtain $(M_1 \times M_2)/(8\times8)$ sub-blocks; then performed DCT to each sub-block to obtain 8×8 coefficient matrix. After that disturbance the coefficient matrix of $Block(i,j)$, using the multiplicative disturbance to tune the values of coefficient matrix accordance to the value of watermark image $W(i,j)$, namely

$$C_{Block(i,j)}=\begin{cases}C_{Block(i,j)}(1+\alpha) & W(i,j)\neq 0\\ C_{Block(i,j)}(1-\alpha) & W(i,j)=0\end{cases} \quad (3)$$

where α is disturbance factor, which usually take a small positive number. Finally, perform inverse *DCT* transform of the disturbance image, merge image blocks and treat them as the watermark image. Extract the digital watermark information can be realized by inverse operation.

Fig.1 Original image, embedded watermark image, original watermark, extracted watermark

This paper take Lena image as the original image, using the above method to embed and extract the watermark, where *a*=0.04. And is show in Figure (1) above. Meanwhile, in order to analyze the quality of the watermark image, using the *PSNR* (Peaks Signal to the Noise ratio)[8,9] as a watermark reconstructed image quality evaluation

$$PSNR = 10\lg\frac{f_{\max}^2}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[\hat{f}(x,y)-f(x,y)]^2} \quad (4)$$

where $f(x,y)$ is original image information, $\hat{f}(x,y)$ is the sum of original image and noise, $f_{\max}=\max[f(x,y)]$. In general, human vision is difficult to distinguish the difference of the original image and the reconstructed image when *PSNR*>30. The reconstructed image remains a very good quality and meets the imperceptibility property, which is the reason that the value of α is 0.04. In addition, to eliminate the observer's experience, the subjective factors and objective factors of physical condition, the experiment shall use the normalized correlation coefficient(NC)for quantitative evaluation[10] on the similarity of the extracted watermark and original watermark. It is defined as:

$$NC(W,\tilde{W})=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}w(i,j)\cdot\tilde{w}(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}w^2(i,j)}\cdot\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\tilde{w}^2(i,j)}} \quad (5)$$

In general, extracted watermark and original watermark satisfies $NC(W,\tilde{W})>0.85$ when the watermark image was attacked; the extracted watermark has good similarity with the original watermark. The watermark basically meet the requirements of robustness, and the greater the correlation value, the better the robustness.

3.2 Analysis of Watermark Attack

In order to detect imperceptibility and robustness of the algorithm, all kinds of noise attack are applied to watermarked Lena image. These attacks include Gaussian noise, Poisson noise, salt and pepper noise and multiplicative noise. Spin attack, graffiti attacks, cutting attack, as well as sharpening, zoom processing, compression processing, etc. are also applied. Various attacks effect as shown in Figure (from 2 to 15) below:

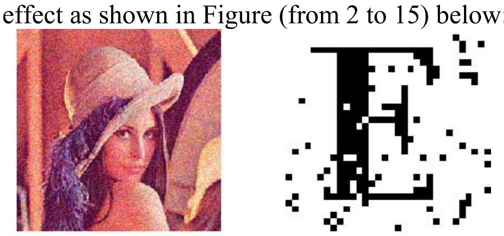

Fig.2 Attacked by Gauss noise and extracted watermark image $\mu=0,\sigma=0.01$

Fig.3 Attacked by Gauss noise and extracted watermark image
$\mu = 0, \sigma = 0.02$

Fig.4 Attacked by Poisson noise and extracted watermark image

Fig.5 Attacked by salt and pepper and extracted watark image

Fig.6 Attacked by multiplicative noise and extracted watermark image

Fig.7 Attacked by rotation and extracted watermark image
$\theta = 30^0$

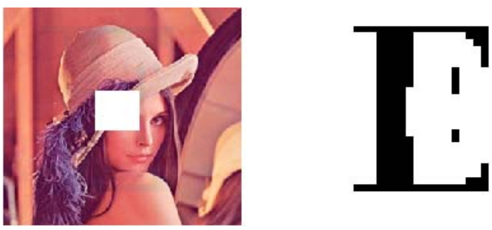

Fig.8 Attacked by cropping and extracted watermark image

Fig.9 Attacked by cutting edge and extracted watermark image

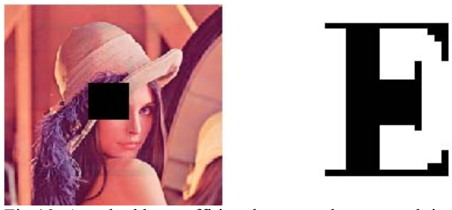

Fig.10 Attacked by graffiti and extracted watermark image

Fig.11Attacked by unsharp and extracted watermark image

Fig.12 Attacked by compress and extracted watermark

Fig.13 Attacked by compress and extracted watermark image (60%)

Fig.14 Attacked by overall mosaic and extracted watermark image

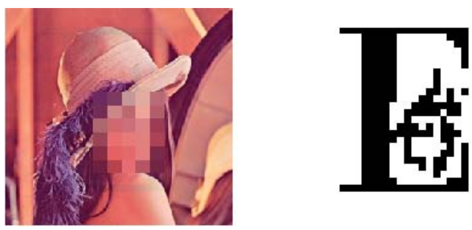

Fig.15 Attacked by local mosaic and extracted watermark image

The table 1 gives the test results for the embedded watermark algorithm for a variety of attacks, which the PSNR represent peak signal to noise ratio of the attacked image, NC represent the correlation of the embedded watermark and the extract watermark.

TABLE 1
THE TEST RESULTS OF VARIOUS ATTACKING ALGORITHM

Attack Method	No Attack	Gaussian noise 1	Gaussian noise2	Poisson noise	salt and pepper noise	multiplicative noise	rotation attack
$psnr$	35.425	20.187	17.698	24.744	23.849	30.849	16.958
NC	0.9999	0.9437	0.9133	0.9963	0.9194	0.9927	0.7988
cropping	cutting edge	graffiti attack	unsharp filter	compression processing1	compression processing2	Mosaic attack 1	Mosaic attack 2
15.543	25.397	21.949	20.543	26.239	23.561	21.002	24.637
0.9781	0.9637	0.9941	0.9475	0.9735	0.9451	0.9327	0.9576

It is easy to draw from the table 1: the watermark image has good imperceptibility. At the same time, through a variety of attacks to the embedded watermark image, the extracted watermark image and the original watermark image has a very good correlation, in line with the requirements of the watermark robustness. Table 2 is the comparison of various attacking styles that can be withstood between algorithm of the reference [11] and the proposed algorithm in the paper.

TABLE 2
THE COMPARISON OF ATTACKING STYLES THAT CAN BE WITHSTOOD BETWEEN TWO DIFFERENTIAL ALGORITHM

	noise attack	rotation attack	enlarge processing	unsharp filter	compression processing	global Mosaic attack	local Mosaic attack
Reference 11	sick	sick	no	sick	no	no	no
The proposed algorithm	yes	yes	yes	yes	yes	yes	yes

It is not difficult to draw from the table 2: the proposed algorithm in the paper can withstand the more attacks such as enlarge processing, compression processing and Mosaic attack. In various noise attacks, rotation attack, weakened processing and so on, the correlation in this paper is much more than that of reference [11].

IV. CONCLUSIONS

This paper analyzes the characteristics of the basic principles and coefficients feature of discrete cosine transform. The color image is divided into block first, and then digital watermark is embedded in original image by subtle perturbations of corresponding coefficients of discrete cosine transform. And various attacks are applied to the embedded watermark image. From the test results, it could be easily gotten that the algorithm has good imperceptibility and robustness, moreover, the algorithm is feasible and simple. Embedded watermark into the different alternating coefficients and the direct coefficient of discrete cosine transform will be further studied, and the effect will be compared.

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Taiyue Wang was born in Huangshi City, Hubei Province, currently doing a doctorate in mathematics from China University of Geosciences, Wuhan, China. He has been a lecturer at the School of Mathematics and Statistics Physics, South Central University for Nationalities, Wuhan, China. His research interests include Generalized Gaussian signal processing, information security and image processing.

Hongwei Li received the Ph.D. degree in applied mathematics from Peking University, Beijing, China, in 1996. From July 1996 to July 1998, he was a postdoctoral fellow with the Institute of Information Science, Beijing Jiaotong University, Beijing, China. Since 1999, he has been a professor at the School of Mathematics and Physics, China University of Geosciences, Wuhan, China. His research interests include statistical signal processing, blind signal processing, multidimensional signal processing, and time series analysis.