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A Digital Watermarking Algorithm Based On DCT and DWT

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Abstract—**This paper introduces an algorithm of digital watermarking based on Discrete Cosine Transform(DCT) and Discrete Wavelet Transform(DWT). Accoring to the characters of human vision, in this algorithm, the information of digital watermarking which has been discrete Cosine transformed, is put into the high frequency band of the image which has been wavelet transformed. Then distills the digital watermarking with the help of the original image and the watermarking image. The simulation results show that this algorithm is invisible and has good robustness for some common image processing operations.**

Index Terms—**digital watermarking; discrete cosine transform(DCT); discrete wavelet transform(DWT); high frequency band; streak block**

I. INTRODUCTION

With the redundancy of the medium as image and voice, digital watermarking technology is to use the digital embedding method to hide the watermarking information into the digital products of image, visible and video. Seen form the field of signal process, the watermarking signal being embeded into carrier is as a feeble signal to add into a strong background. As long as the intensity of watermarking is lower than the contrast restriction of human visible system(HVS) or the apperceive restriction of human audio system(HAS), the wartermaking signal won't be felt by HVS or HAS. With the characters and important application, digital wartermaking technology has been got more and more attention [1][2]. In the future the main development of digital wartermaking is like this: copyright protection, pirate tracking, copying protection, image authentication, cover-up communication, classification control of digital wartermaking video and so on. And the common charaters of digital watermarking is: insensitivity, secrecy, robustness and insurance. According to the different partitions, watermark can be parted in different types like these: significant watermark and the insignificant; the visible and the invisible; the brittle and the steady; the spatial domain watermark and the transformed domain watermark; the blind, the semi-blind and the non-blind. One another partition is carrier and there are image watermark, audio watermark, video watermark, text watermark and so on.

The current classical algorithm contains spatial domain algorithm and transformed domain algorithm. With the spatial domain algorithm, the embedding and the distilling of watermarking are finished in spatial domain, by amending directly or comparing the gray-level value or colour value. The classical spatial domain algorithms including several ways as follow: the least signaficant bit(LSB) [3], Patchwork method with streak block mappedcoding, the method based on district intersecting [4] and so on. Then the main current transformed domain algorithms are spread spectrum, DCT transformation method and DWT transform method.

This paper introduces an algorithm of digital watermarking based on Discrete Cosine Transform(DCT) and Discrete Wavelet Transform(DWT). The watermarking image will be discrete Cosine transformed at first. Because these DCT modulus contain the low frequency information of watermarking image, as long as these information do not lose or lose little then the watermarking image can be renewed well. This enhance the robustness and concealment. The host image I is decomposed through DWT transform, then choose the appreciate wavelet modulus in the high frequency level. The watermarking information are embedding into the corresponding position. Make the whole image IDWT trandformaed and get the watermarked image I′ . The watermarking distilling is quite the contrary.

II. DISCRETE COSINE TRANSFORM

With the character of discrete Fourier transform(DFT), discrete cosine transform(DCT) turn over the image edge to make the image transformed into the form of even function. It's one of the most common linear transformations in digital signal process technology. Two-dimensional discrete cosine transform(2D-DCT) is defined as

$$F(jk) = a(j)a(k)\sum_{m=0}^{N-1}\sum_{n=0}^{N-1} f(mn)cos\left[\frac{(2m+1)j\pi}{2N}\right]cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (1)$$

The corresponding inverse transformation(Whether 2D-IDCT) is defined as

$$f(mn) = \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} a(j)a(k)F(jk)cos\left[\frac{(2m+1)j\pi}{2N}\right]cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (2)$$

The 2D-DCT can not only concentrate the main information of original image into the smallest low-

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frequency coefficient, but also it can cause the image blocking effect being the smallest, which can realize the good compromise between the information centralizing and the computing complication. So it obtains the wide-spreading application in the compression coding.

III. Discrete Wavelet Transform

Wavelet tramsform is a time domain localized analysis method with the window's size fixed and form convertible. There is quite good time differentiated rate in high frequency part of signals DWT transformed. Also there is quite good frequency differentiated rate in its low frequency part. It can distill the information from signal effectively.

The basic idea of discrete wavelet transform(DWT) in image process is to multi-differentiated decompose the image into sub-image of different spatial domain and independent frequency district [5][6]. Then transform the coefficient of sub-image. After the original image has been DWT transformed, it is decomposed into 4 frequency districts which is one low-frequency district(LL) and three high-frequency districts(LH,HL,HH). If the information of low-frequency district is DWT transformed, the sub-level frequency district information will be obtained. A two-dismensional image after three-times DWT decomposed can be shown as Fig.1. Where, L represents low-pass filter, H represents high-pass filter. An original image can be decomposed of frequency districts of HL1, LH1, HH1. The low-frequency district information also can be decomposed into sub-level frequency district information of LL2, HL2, LH2 and HH2. By doing this the original image can be decomposed for n level wavelet transformation.

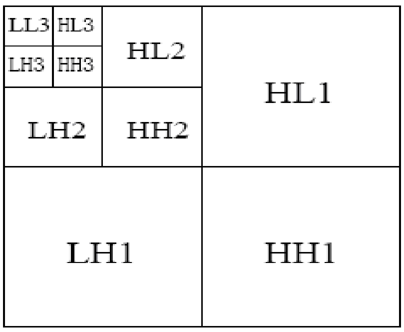

Figure 1. Sketch Map of Image DWT Decomposed

The informaton of low frequency district is a image close to the original image. Most signal information of original image is in this frequency district. The frequency districts of LH, HL and HH respectively represents the level detail, the upright detail and the diagonal detail of the original image.

According to the character of HVS, human eyes is sensitive to the change of smooth district of image, but not sensitive to the tiny change of edge, profile and streak. Therefore, it's hard to conscious that putting the watermarking signal into the big amplitude coefficient of high-grequency band of the image DWT transformed. Then it can carry more watermarking signal and has good concealing effect.

IV. Watermark Embedding and Distilling

The decomposing process of delamination DWT for image frequency is alike the signal disposeing process of HVS. By using the characters of delamination DWT, the concealing and the robustness of watermark can be balanced. Then it become the main choice of watermark embedding in transformed domain.

A. Watermark Embedding:

The way of watermark embedding is shown in Fig.2. It contains some steps as follow:

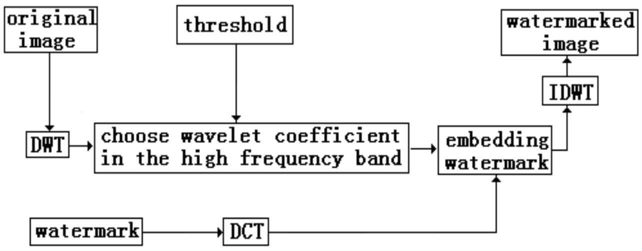

Figure 2. Sketch Map of Watermark Embedding

Step A: For improving the robustness of the watermark algorithm and the secrecy of watermarking image, transform the watermark, that is to make the image DCT transformed and a disordered image will be obtained.

Step B: DWT transform: Decompose the host image X by L-levels using two-dimensional DWT. Then a appoaching sub-image(low frequency band information) and 3L detail sub-images(high-frequency band information) are obtained. How to choose the DWT levels L is depended on the sizes of the original image and the watermarking signal. The higher DWT level is, the better the concealing effect of embedding watermark is.

Step C: Choose the streak blocks: The high frequency band information of DWT image is plotted into $2*2$ image sub-blocks B_k. Then calculate entropy and square values of each image sub-block B_k. The image sub-block with small value of entropy should be smooth block, which with big value should be streak block or edge block. And the square value of streak block is small, the one of edge block is bigger. By choosing the right threshold of entropy and the square, the streak blocks wanted $U_k(k=1,2,\cdots,\ P\times Q)$ will be obtained.

Step D: Embedding the watermark: Amend the wavelet coefficient values C_k of the chosen streak blocks B_k to complete the watermark embedding. And the embedding formula is as follow:

$$C_k' = C_k + a \times v_k,\ \ k = 1,2,\cdots,\ P\times Q \tag{3}$$

Where, C_k represents the former wavelet coefficient value of streak sub-block U_k, V_k represents the No. k componented weight of one-dimensional digital watermarking sequence V, C_k' represents the new wavelet coefficient value of streak sub-block U_k, a represents the embeding depth for digital watermarking.

Step E: Inversing transform: After embeding the watermarking signal, unite the information of the lowest frequency band and the mended high frequency band. Then the wavelet transform of the image is inversed by the L-level, and the watermarked image is obtained.

B. Watermark Distilling:

The way of watermark distilling is shown in Fig.3. It contains some steps as follow:

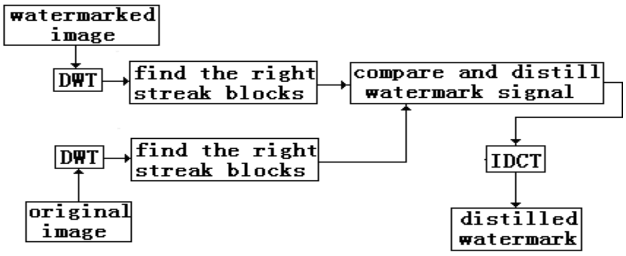

Figure 3. Sketch Map of Watermark Distilling

Step A: DWT transform: Transform the original image and the watermarked image by L-levels using DWT. And the information of the lowest frequency band and the high frequency band are obtained.

Step B: Make sure the streak blocks: The high frequency band information, both of DWT image of the original and the watermarked one, is plotted into $2*2$ image sub-blocks. The streak block U , which is obtained from the high frequency band of original image after being DWT transformed, can be as index by using its position. Through the index, the streak block U' , corresponding to the sub-block of the high frequency band of the DWT transformed watermarked image, is obtained.

Step C: Distilling the watermarking signal V' : Calculate the entropies $H(U_k)$ and $H\left(U_k'\right)$, which are respectively corresponding to the streak block U_k and U_k'. And the result of $H(U_k)-H\left(U_k'\right)$ is easily obtained. When this value is bigger than a certain threshold value, it's thought that there is watermarking componented weight information in the streak block U_k' of watermarked image. Then it's signed as 1, else 0.

Step D: Inversing transformation of watermark: Then the discrete cosine transform of the disordered watermarking image is inversed, and the watermark image is obtained.

V. THE ANALYSIS OF ROBUSTNESS AND CONCEALING

Generally speaking, the evaluation of a watermark algorithm contains two parts: robustness and concealing. The comparability of the distilled watermark with the original watermark is quantitatively analysised by using Normalized Cross-Correlation (NC)[7]. The Normalized Cross-Correlation(NC) is defined as

$$NC = \frac{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2} W(i,\ j)\cdot W'(i,\ j)}{\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,\ j)]^2}\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W'(i,\ j)]^2}} \qquad (4)$$

The value of NC is between 0 and 1. And the bigger the value is, the better the watermark robustness is [7-8].

The concealing of the watermark is quantitatively analysised by using Peak Singal to Noise(PSNR). This Peak Singal to Noise(PSNR) is defined as

$$PSNR = 10log_{10}\frac{A^2}{\frac{1}{N\times M}\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,\ j)-f'(i,\ j)]^2} \qquad (5)$$

Its unit is db. And the bigger the PSNR value is, the better the watermark conceals.

VI. SIMULATION EXPERIMENT

For testing the performance of this algorithm, the experiments is simulated with the software MATLAB. In the following experiments, the gray-level image with size of 256*256 "Lena" is used as host image to embed watermark. Another binary image with size of $32*32$ "logo" is as the watermark.

The original watermark and the watermark DCT transformed are shown in Fig.4. It is hard to recognize the transformed watermark image. The original host image, watermarked image and the distilled watermark image are shown in Fig.5. This watermarked image is quite close to original image in vision impression. There is no distinct differences between these two images only with eyes. That is to say, this algorithm can conceal watermark well. And the PSNR is 50.0285 db, which is better than the PSNR of Cox algorithm[8] (42.3754db). It improves the concealing capability. On the other hand, the NC of original watermark and distilled watermark is 0.9782, which is well in effect.

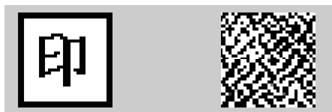

Figure 4. original watermark and the watermark DCT transformed

In order to test the performance, the watermarked image suffers some different signal attacks, which includes filer, sharp enhancing, adding salt noise, image compression, image cutting and rotation. The simulation results, including the watermarked image and distilled watermark under different kinds of signal attack [9], are shown from Fig.6 to Fig.11.

Seen from Fig.6 to Fig.10, the simulation results suggest that it can renew the watermark image well after this watermarked image is attacked of those processing. Rotate the watermarked image for 30°and the result is shown in Fig.11. This distilled watermark is a distorted image. The exact NC values and PSNR values of the processings are shown in Tab. I .

Table I. THE PARAMETER VALUES OF ATTACKED WATERMARKED IMAGE

Image type	NC	PSNR
Filter	0.9132	35.5801
Enhancing	0.8962	32.0763
Noise	0.8643	28.0851
Cutting	0.7089	27.3359
Compression	0.8518	31.7749
Rotation	0.5034	21.5003

Simulation results suggest that this watermark algorithm can be robust against many common different types of attacks such as filer, sharp enhancing, adding salt noise, image compression, image cutting and rotation. But it's a little bad response for ratation attack and it should be improved for it.

Figure 5. Original Host Image, Watermarked Image and Distilled Watermar (a)Original Host Image (b)Watermarked Host Image (c)Distilled Watermark

Figure 6. Result Under Filter

Figure 7. Result Under Sharp Enhancing

Figure.8.Result Under Adding Noise

Figure.9 Result Under Cutting 1/4 Image

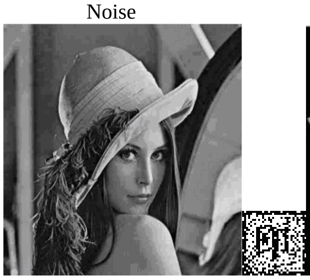

Figure.10 Result Under Compression

Figure.11 Result Under Rotation

VII. CONCLUSION

This paper introduces a discrete wavelet transform(DWT) digital watermark algorithm based on human vision characters. By using the block technology, watermarking signal is embedded into the high frequency band of wavelet transformation domain. And before embedding this watermark image has been dicrete cosine transformed in order to improve its robustness. The simulation results suggest that this watermarking system not only can keep the image quality well, but also can be robust against many common image processing operations of filer, sharp enhancing, adding salt noise, image compression, image cutting and so on. This algorithm has strong capability of embedding singal and anti-attack.

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