Combined DWT-DCT Based Digital Image Watermarking Technique for Copyright Protection

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Abstract— **A combined DWT and DCT based watermarking technique with low frequency watermarking with weighted correction is proposed. DWT has excellent spatial localization, frequency spread and multi-resolution characteristics, which are similar to the theoretical models of the human visual system (HVS). DCT based watermarking techniques offer compression while DWT based watermarking techniques offer scalability. These desirable properties are used in this combined watermarking technique. In the proposed method watermark bits are embedded in the low frequency band of each DCT block of selected DWT sub-band. The weighted correction is also used to improve the imperceptibility. The extracting procedure reverses the embedding operations without the reference of the original image. Compared with the similar approach by DCT based approach and DWT based approach, the experimental results show that the proposed algorithm apparently preserves superior image quality and robustness under various attacks such as JPEG compression, cropping, sharping, contrast adjustments and so on.**

Index Terms— **Digital watermarking, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT).**

I. INTRODUCTION

In the recent years, it becomes a daily need to create copy, transmit and distribute digital data as a part of widespread multimedia technology by means of the World Wide Web. Hence copyright protection has become essential to avoid piracy. Digital image watermarking provides the essential mechanism for the ownership authentication.

Image watermarking is the process of inserting hidden information in an image by introducing modifications of minimum perceptual disturbance. Robustness, perceptual transparency, capacity and blind watermarking are four essential factors to determine quality of watermarking scheme [1]. Image watermarking techniques can be divided into two groups in accordance with processing domain of host image. One is to modify the intensity value of the luminance in the spatial domain [2] and the other is to change the image coefficient in a frequency domain [3]-[4].

Commonly used frequency-domain transforms include the Discrete Wavelet Transform and the Discrete Cosine Transform. However, DWT has been used in digital image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system and DWT gives perfect reconstruction of decomposed image. The DCT has special property that most of the visually significant information of the image is concentrated in just a few coefficient of the DCT. Moreover DCT based watermarking techniques offer compression while DWT based watermarking techniques offer scalability. Further performance improvements in DWT-based digital image watermarking algorithms and DCT-based watermarking algorithms could be obtained by combining DWT with DCT. The idea of applying two transforms is based on the fact that combined transforms could compensate for the drawbacks of each other, resulting in effective watermarking.

In nature image, the energy of each block is concentrated on the low frequency after transformation. It is known that embedding watermark in low frequency makes the watermark perceptible. On the other hand, to survive lossy data compression, watermark information should not be inserted into the higher frequency. Traditional techniques select the middle-frequency range to embed the watermark. For example, Al-Haji's [5] proposed embedding visually recognizable patterns into the images by selectively modifying the middle-frequency parts of the image. However, in our proposed method, watermark is embedded into the low frequency band of the DCT block of selected DWT sub-band. To achieve perceptual invisibility of the watermark, the weighted correction which is an approach to justify the watermarked image on the spatial domain is proposed.

Binary bits of watermark are embedded into the low frequency of DCT coefficients of the selected frequency sub-band of DWT. For embedding we use two uncorrelated pseudorandom sequences. One sequence is used to embed watermark bit one and another is used to embed watermark bit zero. The algorithm for watermark extraction is reversing the embedding operations without the reference of the original image. Section II describes the proposed framework for watermarking. The performances are evaluated in Section III. Finally, the conclusion is given in Section IV.

II. THE PROPOSED FRAMEWORK

In this section we will discuss about the watermark bits embedding process and extraction the watermark from the watermarked image.

A. Embedding Approach

To embed watermark bits in the host image the following steps are needed.

1) *DWT transform:* Apply DWT on the host image to decompose it into four non-overlapping multi-resolution coefficient sets. Fig. 1 shows the four non-overlapping coefficient sets of an image. The coefficient sets are

$$W_{LL}^{J} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} g(x)g(y)W_{LL}^{J-1}(2u-x)(2v-y) \tag{1}$$

$$W_{LH}^{J} = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} g(x)h(y)W_{LL}^{J-1}(2u-x)(2v-y) \tag{2}$$

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$$W_{HL}^{J} = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} h(x)g(y)W_{LL}^{J-1}(2u-x)(2v-y) \quad (3)$$

$$W_{HH}^{J} = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} h(x)h(y)W_{LL}^{J-1}(2u-x)(2v-y) \quad (4)$$

Where J is the level of the 2-D DWT, $g(n)$ and $h(n)$ are the impulse response and $W_{LL}^{0} = W(u,v)$ is the original image. Choose W_{HL} for embedding watermark bits.

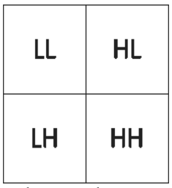


Fig. 1 Single level DWT decomposition of an image.

2) *Divide the horizontal coefficients set into 4X4 blocks:* Divide the chosen coefficients set W_{HL} into 4x4 blocks. Fig. 2 shows a 4×4 block of chosen coefficient set.

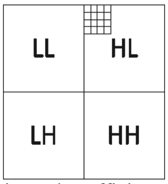


Fig. 2 Divide the horizontal coefficients set into 4X4 blocks.

3) *DCT transform on selected coefficient set:* Apply DCT on each block of the chosen coefficient set W_{HL} .The DCT can be defined by the following equation:

$$F(u,v) = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} g(x,y,u,v) \quad (5)$$

Where the kernel is given by following equation:

$$g(x,y,u,v) = \alpha(u)\alpha(v)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad (6)$$

where $\alpha(u) = \alpha(v) = \frac{1}{\sqrt{N}}$ for $u,v = 0$,otherwise $\alpha(u) = \alpha(v) = \sqrt{\frac{2}{N}}$

4) *Scramble watermark image:* Scramble the watermark image with Arnold Transform to increase the robustness of a model against cropping. This increases the watermark secrecy and security level. We can get back the original watermark image by applying Arnold transform on the scrambled image. Arnold transform equation is shown below:

$$\begin{Bmatrix} P' \\ Q' \end{Bmatrix} = \left\{ \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{Bmatrix} P \\ Q \end{Bmatrix} \bmod N \right\} \quad (7)$$

Where, P and Q denote the coordinate of pixels of the original watermark, P' and Q' denote the coordinate of pixels of the transformed watermark.

5) *Convert watermark into binary format:* Convert the watermark image into binary format.

6) *Generate pseudorandom sequences:* Generate two uncorrelated pseudorandom sequences by using a key. One sequence is used to embed the watermark bit 0 (seq_0) and the other sequence is used to embed the watermark bit 1 (seq_1) . Pseudorandom sequences are used to increase security level.

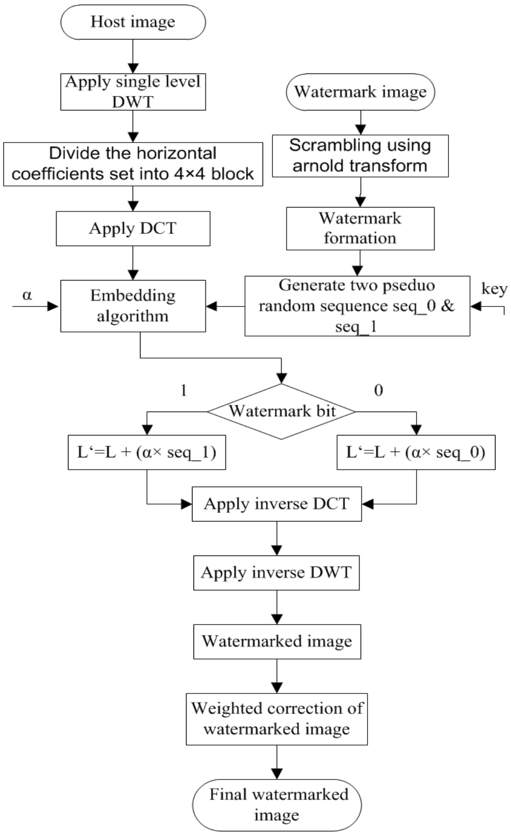


Fig. 3 The proposed framework for embedding watermark bits into the host image.

7) *Low frequency embedding:* Embed the two pseudorandom sequences with a gain factor α in the DCT transformed 4×4 blocks of the selected DWT coefficient sets of the host image. Instead of embedding in all coefficients of the DCT block, it embeds only to the low frequency DCT coefficients. The DCT coefficients are stored according to a zigzag format, as shown in Fig. 4. $C(i,j)$ indicates the embedding position of the low frequency.

If we denote L as the matrix of the low frequency coefficients of the DCT transformed block, then embedding is done as following equation.

If watermark bit is 0, then

$$L' = L + (\alpha \times seq\_0) \quad (8)$$

If watermark bit is 1, then

$$L' = L + (\alpha \times seq\_1) \quad (9)$$

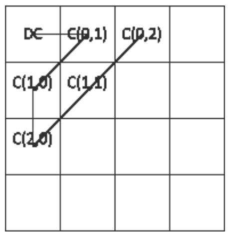


Fig. 4 The embedding position of the low frequency.

8) *Inverse DCT:* Perform the inverse DCT on each block after its low-band coefficients have been modified to embed the watermark bits as described in the previous step.

9) *Inverse DWT:* Perform the inverse DWT on the DWT transformed image, including the modified coefficient set, to produce the watermarked host image.

10) Justify the watermarked image: Compare the watermarked image with original image. Let D be the difference in gray levels between the original image I_1 and the watermarked image I_2, it can be represented as:

$$D = I_1(i,j) - I_2(i,j), 0 \le i < N_1, 0 \le j < N_2 \tag{10}$$

Let M denotes the magnitude suppression of D, that is

$$M_{i,j} = D_{i,j} \times c \tag{11}$$

The constant value of c is used to improve the invisibility of watermark. Then the watermarked image I_2 is modified as:

$$I'_{2_{i,j}} = I_{2_{i,j}} + M_{i,j} \tag{12}$$

I'_2 is the final watermarked image after weighted correction.

B. Extracting approach

To extract watermark bits from the watermarked image the following steps are needed.

1) *Filtering operation:* Perform pre-filtered operations on the watermarked image.

2) *DWT transform:* Apply DWT on the pre-filtered watermarked image to decompose it into four non-overlapping multi-resolution coefficient sets. Choose W_{HL} coefficient set.

3) Divide the horizontal coefficients set into 4X4 blocks: Divide the chosen coefficient sets into 4 x 4 blocks.

4) DCT transform on selected coefficient set: Apply DCT on each block in the chosen coefficient set.

5) Generate pseudorandom sequences: Regenerate the two pseudorandom sequences seq_0 and seq_1 using the same key that was used in the watermark embedding procedure.

6) *Calculate correlation:* For each block in the coefficient set W_{HL} calculates the correlation between the low-band coefficients and the two generated pseudorandom sequences. If the correlation with the seq_0 is higher than the correlation with seq_1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1.

7) *Reconstruct extracted watermark:* The scrambled watermark is reconstructed using the extracted watermark bits.

8) Compute the similarity: Scramble the extracted watermark with Arnold Transform with the same key times and gain the scrambled watermark. Compute the similarity between the original and extracted watermarks.

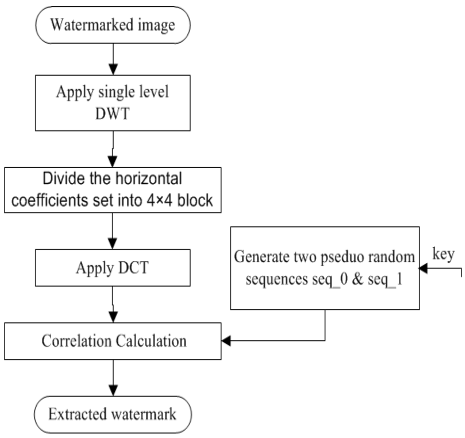


Fig. 5 The proposed framework for extracting watermark from the watermarked image.

III. PERFORMANCE EVALUATION

Among various test images employed in experiments, the 512×512 "Lena" image which is shown in Fig. 6 (a) is used to show the effectiveness of the proposed method. The 64×64 watermark is shown in Fig 6 (b).

(a) (b)

Fig. 6 (a)"Lena" image which worked as the host image (b) Watermark image which is embedded to the host image.

Imperceptibility: Imperceptibility means that the perceived quality of the host image should not be distorted by the presence of the watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio is typically used. The PSNR has been utilized to calculate similarity between the original image and the watermarked image.

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \tag{13}$$

$$\text{where, } MSE = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}[I_1(i,j) - I'_2(i,j)]^2}{N \times N} \tag{14}$$

The MSE (mean square error) will be computed firstly and then the value for PSNR will be computed secondly.

Robustness: Robustness is a measure of the immunity of the watermark against attempt to remove it by different types of attacks. We measure the similarity between the original watermark and the extracted watermark from the attacked image using the Normalized Correlation (NC) factor.

$$NC = \frac{\sum_{j=0}^{J-1}\sum_{k=0}^{K-1} W_1(j,k)W_2(j,k)}{\sum_{j=0}^{J-1}\sum_{k=0}^{K-1} W_1(j,k)^2} \tag{15}$$

Fig. 7 (a) shows the watermarked "Lena" image and the PSNR of the watermarked "Lena" image is about 35.6324dB. Fig. 7 (b) shows the recovered watermark.

(a) (b)

Fig 7. (a) Watermarked image which is found after embedding watermark (b) Extracted watermark from watermarked image.

A. JPEG Compression

The watermarked image I_2 in Fig. 7(a) is transformed into a new image after JPEG compression in which the quality factor is 50 and it is shown in Fig. 8(a). The image watermark extracted from it is shown in Fig. 8(b).

(a) (b)

Fig. 8 (a) JPEG Compression of Watermarked image (b) Extracted watermark from compressed watermarked image.

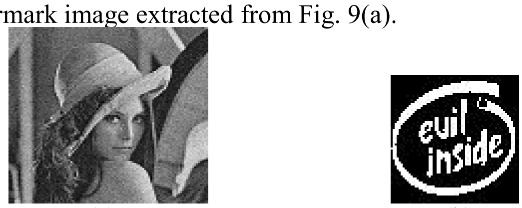
In TABLE I some data are given for JPEG compression.

TABLE I
JPEG COMPRESSION DATA

Quality factor	PSNR	NC
90	32.9204	1
70	32.8063	1
50	29.1601	0.9650

B. Noise attacking

The watermarked image I_2 in Fig. 7(a) is transformed into Fig. 9(a) after adding Gaussian noise, Fig. 9(b) is the watermark image extracted from Fig. 9(a).



(a) (b)

Fig. 9 (a) Watermarked image after adding Gaussian noise (b) Extracted watermark from Gaussian noise attacked watermarked image.

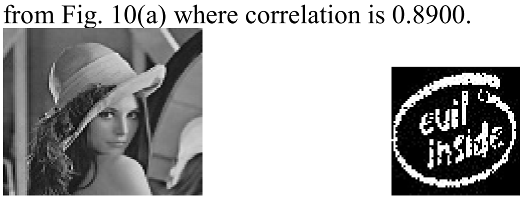
Some data are provided in TABLE II with the watermarked image I_2 is attacked by various kinds of noise.

TABLE II
DIFFERENT TYPES OF NOISE ATTACKED DATA

Salt and Pepper noise	Gaussian noise	Speckle noise
Strength=0.01	Average=0, Variance=0.002	Variance=0.01
PSNR=25.9093	PSNR= 27.6189	PSNR=27.3263
NC=0.9473	NC=0.9878	NC=0.9841

C. Filtering

The watermarked image I_2 in Fig. 7(a) is transformed into Fig. 10(a) after Weiner filtering, Fig. 10(b) is the Extracted image from Fig. 10(a) where correlation is 0.8900.

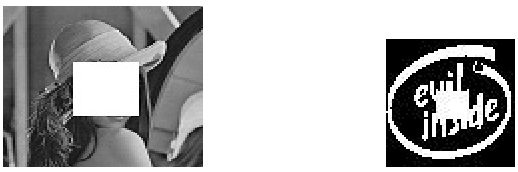


(a) (b)

Fig. 10 (a) Watermarked image after Weiner filtering (b)Extracted watermark from filtered watermarked image.

D. Cropping

Cropping refers to the removal of the any parts of an image. Fig. 11(a) is shown 128×128 cropped of Fig. 7(a). Fig. 11(b) is the extracted watermark.



(a) (b)

Fig. 11 (a) Watermarked image after cropped (b) Extracted watermark from cropped watermarked image.

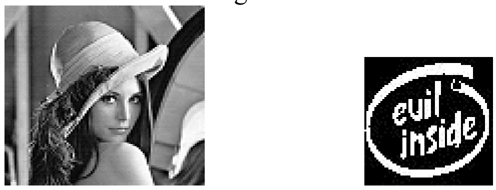
The experimental result of proposed method is given in TABLE III after the watermarked image is cropped.

TABLE III
CROPPING DATA

Cropped area	PSNR	NC
32×32	29.8425	0.9939
64×64	25.6530	0.9702
80×80	22.9744	0.9520
128×128	18.5870	0.9182

E. Contrast Adjustment

The watermarked image I_2 in Fig. 7(a) is transformed into Fig. 12(a) after Contrast Adjustment and Fig. 12(b) is the extracted watermark from Fig. 12(a). The correlation of extracted watermark with original watermark is 0.9983.



(a) (b)

Fig. 12 (a) Watermarked image after Contrast Adjustment (b) Extracted watermark from attacked watermarked image.

In TABLE IV some comparison result of extracted image from different attacked watermarked image between my proposed method and ZHAO's [6] method are shown.

TABLE IV
COMPARISON RESULT

Attack	ZHAO's method	Proposed method
Gaussian noise (Average=0,Variance=0.002)	0.9646	0.9878
Salt and pepper noise (Strength=0.01)	0.9473	0.9473
JPEG Compression (Quality=90)	0.9988	1
Cropping (128×128)	0.8666	0.9182
Wiener filter	0.9192	0.8900

IV. CONCLUSIONS

In this paper, a combined DWT and DCT based watermarking technique with low frequency watermarking with weighted correction has been proposed. In this technique watermark is mainly inserted into the low frequency of each DCT block of selected coefficient set of DWT domain. To increase the imperceptibility, the watermark image is adjusted by the weighted correction in the spatial domain. The results of experiments have showed that the algorithm has better visibility and has stronger robustness when it is attacked by JPEG compression, cropping, contrast adjustments, filtering, noises and so on. The experimental result shows that in most of the cases the correlation between the original watermark and the extracted watermark is more than 0.9. These results demonstrate that the proposed method is suitable candidate for copyright protection.

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