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Novel Efficient Image Watermark Algorithm Based on DFT Transform

Hai-yang Ding[1,2]

[1]Information Security Center, Beijing University of Posts and Telecommunications, Beijing 100876, China
[2]College of Information Engineering, Beijing Institute of Graphic Communication, Beijing 102600, China
o_dhy@163.com

Abstract

In order to improve watermark capacity, image quality and error correction capability of DFT-based watermark algorithm, this paper proposes a novel efficient image watermark algorithm based on DFT transform. Firstly, the watermark information is encoded by using hybrid error correcting code, and the watermark is embedded into an image, and the code ensures that the correct rate of watermark extraction is 100% in the condition of the watermarked image under attacks. Secondly, through changing the way of embedding watermark into the frequency domain data block, watermark capacity can be increased to 2 times of the original algorithm. Thirdly, through extending the frequency domain region of embedding watermark, visual effect of the watermarked image is obviously improved and watermark capacity can be increased. The experimental results show that the proposed algorithm is significantly better than the original algorithm in robustness, and it can ensure that the correct rate of watermark extraction is 100% after the watermarked image suffered with attacks, and the proposed algorithm and the original algorithm are basically the same in PSNR, and the proposed algorithm is better than the original algorithm in visual effect of watermarked image.

Key word: *Image Watermark; DFT; hybrid error correction code*

1. Introduction

Image watermark is a common technology for copyright protection of digital content. Embedding domain of watermark can be categorized into two domains: spatial domain and transform domain [1]. LSB algorithm [2] is a method in spatial domain. Basically, watermark algorithm in transform domain can be divided into DFT-based algorithm, DCT-based algorithm and DWT-based algorithm, and the idea of realization is similar, watermark value can be embedded by control specific coefficients of transform domain.

The approach in [3] presents a watermark algorithm based on DFT transform which selects groups of DFT coefficients in the low-middle frequency band, and the coefficients in every group are divided into two sub-groups based on a pre-defined pattern, and the energy relationship between these two sub-groups is used to hide the watermark. The method in [4] presents an approach using the fast Fourier transform, which added a template in the Fourier transform domain to render the method robust against rotation and scaling, or aspect ratio changes. The approach in [5] proposes a robust blind color image watermarking in quaternion Fourier transform domain. The approach in [6] proposes a new image watermarking algorithm with reasonable resistance toward desynchronization attacks. Discrete Fourier transform (DFT) is performed on the local feature region (LFR) of an image, and the local image histogram is extracted from a selected DFT amplitude

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range, and the digital watermark is embedded into LFR by reassigning the number of DFT amplitudes in bin groups.

The method in [7] proposes the differential energy watermark (DEW) algorithm for JPEG/MPEG streams which embeds label bits by selectively discarding high frequency DCT coefficients in certain image regions. The approach in [8] presents a DCT-based Watson's imperceptive watermark model resisted down sampling attack. The approach in [9] presents an algorithm which embeds watermark by using DC coefficient of block DCT. The method in [10] proposes a scheme which indicates watermark value through odd-even of the number of high frequency coefficients equal 0. The method in [11] presents a method which embeds watermark using relationship of one coefficient and average of some coefficients.

The method in [12] proposes a blind watermarking algorithm based on maximum wavelet coefficient quantization. The scheme in [13] proposes a robust watermarking algorithm using balanced multi-wavelet transform, and the watermark embedding scheme is based on the principles of spread-spectrum communications to achieve higher watermark robustness, and the strength of the embedded watermark is controlled according to the local properties of the host image. The approach in [14] presents a watermarking algorithm operating in the wavelet domain. Performance improvement with respect to existing algorithms is obtained by means of a new approach to mask the watermark according to the characteristics of the human visual system (HVS). The method in [15] proposes a novel oblivious image watermarking technique for the copyright protection and authentication of still images, based on Discrete Multiwavelet Transform (DMWT) and Quantization Index Modulus Modulation (QIMM). The approach in [16] presents a new wavelet based logo-watermarking scheme for copyright protection of digital image.

There are some other novel watermark approaches. The method in [17] proposes a novel support vector regression based color image watermarking scheme. The method in [18] presents a robust phase watermarking scheme for still digital images based on the sequency-ordered complex Hadamard transform (SCHT). The approach in [19] proposes a blind watermarking scheme based on discrete fractional random transform. The approach in [20] proposes a new image watermarking scheme which is insensitive to geometric distortions as well as common image processing operations. The approach in [21] proposes a novel content-based image watermarking method based on invariant regions of an image.

This paper has realized the watermark algorithm based on DFT transform presented in [3], and analyzed the performance of the algorithm, and then found the shortcomings of the algorithm in watermark capacity, image quality and error correction capability, and as a result a novel efficient image watermark algorithm based on DFT transform is proposed. Firstly, the watermark information is encoded by using hybrid error correcting code, and the watermark is embedded into an image, and the code ensures that the correct rate of watermark extraction is 100% in the condition of the watermarked image under attacks. Secondly, through changing the way of embedding watermark into the frequency domain data block, watermark capacity can be increased to 2 times of the original algorithm. Thirdly, through extending the frequency domain region of embedding watermark, visual effect of the watermarked image is obviously improved and watermark capacity can be increased. The experimental results show that the proposed algorithm is significantly better than the original algorithm in robustness, and it is able to ensure that the correct rate of watermark extraction is 100% after the watermarked image suffered with attacks, and the proposed algorithm and the original algorithm are basically the same in PSNR, and the proposed algorithm is better than the original algorithm in visual effect of watermarked image.

2. Analysis of the Performance of the Original DFT-based Watermark Algorithm

The watermark algorithm based on DFT transform presented in [3] has realized. The watermark is embedded in Discrete Fourier Transform (DFT) domain of an image. After the whole 2D DFT transform of an image, and the data in the low-middle frequency region is divided into 4×4 block, the coefficients in each block are divided into two sub-blocks based on a pre-defined pattern, and the energy relationship between these two sub- blocks is used to hide the watermark. The performance of the original DFT-based watermark algorithm is analyzed as follows.

2.1. Transparency

In this paper, 3 kinds of image are used as a test set, which are 512×512 gray image, 512×512 color image and 500×536 color image. The length of watermarked content is 216 bits, and PSNR statistical results of the original algorithm are shown in Figure 1.

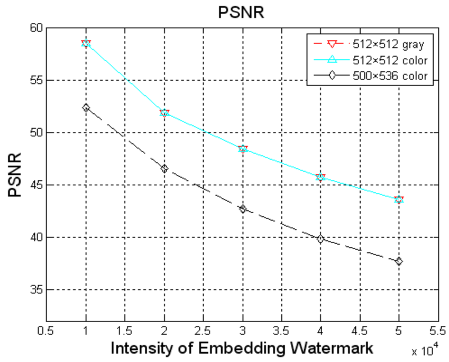
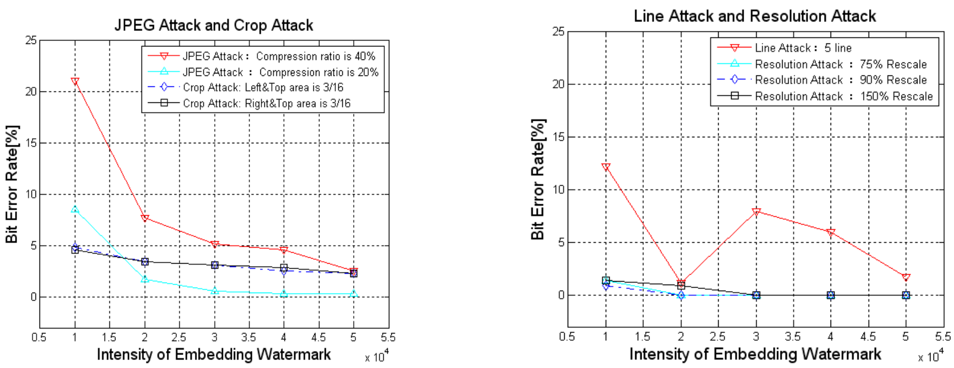


Figure 1. Statistical Results of Original Algorithm

From Figure 1, it can be seen that the transparency of original algorithm is very good even when embedding strength is 50000, and the PSNR of 500×536 color image is lower than other images, because the domain to embed watermark in 500×536 color image is only 256×256.

2.2. Robustness

After extracting the watermark from watermarked images suffered with attacks, bit error rate (BER) can be calculated, and statistical results are shown in Figure 2.



(a) BER under JPEG Attack and Crop Attack (b) BER Under Line Attack and Resolution Attack

Figure 2. Robustness of Original Algorithm

From Figure 2, it can be seen that the original algorithm has good robustness against JPEG attack, crop attack, line attack and resolution attack.

2.3. Shortcomings of the Original Algorithm

2.3.1. Lack of Error Correction Capability: From Figure 2, it can be seen that the original algorithm has not the capability of correcting error. If an error occurs when extracting the watermark from watermarked images suffered with attacks, and the error cannot be corrected, and as a result it is unable to ensure the correct rate of watermark extraction is 100%.

2.3.2. Image Quality Decreased Obviously with Increase of Embedding Capacity: Using the original algorithm, Image quality of watermarked image decreased obviously with the increase of embedding capacity, and this problem is particularly evident in the small picture, and PSNR statistical results of 128×128 gray images are shown in Figure 3.

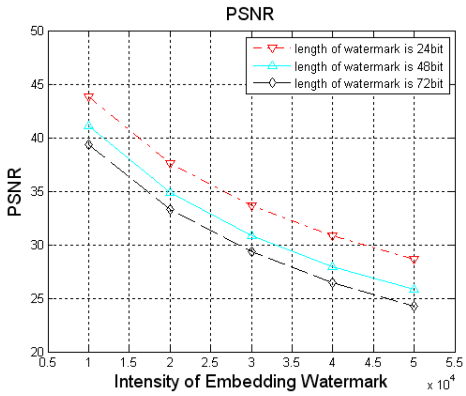


Figure 3. PSNR Statistical Results of 128×128 Gray Images

From Figure 3, it can be seen that the PSNR is lower with the increase of embedding capacity, and the reason is that embedding watermark is realized by modifying the low-middle frequency data. With the increase of embedding capacity, the modified frequency data is more, so the PSNR is lower and with the increase of embedding capacity, the modified data is closer to the center of the frequency data, and the data is closer to low frequency data, and the human eye is more sensitive to low frequency data, therefore the image quality is getting worse.

2.3.3. The Watermark Capacity is Limited: In the original algorithm, the low-middle frequency region selected to embedding watermark is x:1/4×width-3/4×width y:1/4×height-3/4×height, and this area will be referred to as 1/4-3/4 area in the following parts. The watermark capacity limit is C_l in 1/4-3/4 area and the calculation method of C_l is shown in (1):

$$C_1 = \frac{W/2}{4} \times \frac{H/4}{4} \ bit \qquad (1)$$

Because the frequency domain data after DFT transform is the conjugate symmetry, the whole area to embed watermark is half of low-middle frequency region. For example, in a 512×512 image, the capacity limit is: C_l=((512/2)/4)×((512/4)/4)=2048bit; and in a 128×128 image, the capacity limit is: C_l=((128/2)/4)×((128/4)/4)=128bit. With the increase of embedding capacity, the modified data is closer to the center of the frequency data, and it will impact spatial image obviously, and it is not suitable to embed watermark in the center of the frequency data, so the actual watermark capacity must be less than C_l.

Conclusions as a result, the watermark algorithm based on DFT transform has good robustness against geometric attacks, but this algorithm has obvious shortcomings: (1) Lack of error correction capability; (2) Image quality decreased obviously with increase of embedding capacity; (3) The watermark capacity is limited.

3. Compostion of Algorithm Improvement

In this paper, according to the shortcomings of the original algorithm based on DFT transform, DFT-based watermark algorithm will be improved, and the improved algorithm consists of three parts.

3.1. Hybrid Error Correcting Code

In practical engineering, it is necessary that the correct rate of watermark extraction is 100%, and this must be realized by using error correcting code. This paper presents a hybrid error correction code, which is based on 2 basic error correcting codes.

3.1.1. 2 Times Repetition Code: The output watermark code is generated through repeating the original code 2 times, and is embedded into an image. When extracting watermark, 1 bit watermark value can be obtained by using 3 bits include 1 bit original watermark and 2 bits repetition, and if the number of 1 is more than or equal to 2, the current watermark value is 1, otherwise the current watermark value is 0. Advantage of this code is sample and strong error correction capacity, and disadvantage of this code is that occupied capacity is too large.

3.1.2. BCH Code: BCH code is commonly used in the form of (7,4,1) and (15,7,2). (7,4,1) means output code is 7 bits, and information code is 4 bits, and correction capability is 1 bit; (15,7,2) means output code is 15 bits, and information code is 7 bits, and correction capability is 2 bit.Advantages of this code are strong error correction capacity and occupy small capacity; and disadvantage of this code is that the code must use a set of codes as a basic unit, and it is easily resulting in wasted capacity. For example, when using (15,7,2) code, BCH code must use 7 bits as a basic unit, even if original code is 1 bit, and BCH code must use 7 bits as a unit, and output code is 15 bits.

3.1.3. Hybrid Error Correcting Code: In some conditions BCH code leads to waste capacity. Such as, original code is 64 bits when using (15,7,2) code, and length of BCH output code is $64/7\times15+15=150$bits， and this means that 1bit at the end of original code is coded as a unit, and output code is 15 bits, and this lead to waste capacity.

In order to save the watermark capacity, this paper proposes a hybrid error correcting code, which is based on BCH code and 2 times repetition code, the rule is defined as follows:

If original code is n bits when using (15,7,2) code, and m=n/7 which denotes the number of BCH code units, and 7×m bits in front of original code is encoded by using BCH code, and 15×m bits code is generated; And then k=n%7 which denotes the rest code of original code, and k bits is encoded by using hybrid error correcting code:

When $k<5$, k bits is encoded through 2 times repetition code;

When $k\geqslant5$, k bits is encoded through BCH code.

For example, original code is 64 bit when using (15,7,2) code, and m=64/7, and 7×9 bits in front of original code is encoded by using BCH code, and 15×9 bits code is generated; And then k=64%7, and 1 bit is encoded through 2 times repetition code, and output code is 3 bits, as a result total length of hybrid error correcting code is $63/7\times15+1\times3=138$ bits, and this code saves 12 bits capacity compare with BCH code.

After watermark information is encoded through hybrid error correcting code, length of watermark to embed is increased, so this paper proposes the following methods to increase watermark capacity and improve visual effect of the watermarked image.

3.2. Embed 2 Bits Watermark Value in Each 4×4 Block

In the watermark algorithm presented in [3], the data in the low-middle frequency region is divided into 4×4 block, the coefficients in each block are divided into two sub-blocks based on a pre-defined pattern, and the energy relationship between these two sub-blocks is used to hide 1 bit watermark. Figure 4(a), shows the location of the two sub-groups in each 4 × 4 block, so only 1 bit watermark is embedded in each 4×4 block. In order to increase watermark capacity, this paper modifies pre-defined pattern in each block, and the coefficients in each block are divided into four sub- blocks, and the energy relationship between four sub-blocks is used to hide 2 bits watermark. Wi denotes *i-th* watermark value, and $W_{2\times i-1}$ and $W_{2\times i}$ can be embedded in the *i-th* 4 × 4 block. Figure 4(b), shows the location of the four sub-groups in each 4×4 block.

		O	O
		O	O
X	X		
X	X		

(a) The Location of Two Sub- Blocks

Y	Y	O	O
Y	Y	O	O
X	X	Z	Z
X	X	Z	Z

(b) The Location of Four Sub- Blocks

Figure 4. The Location in 4×4 Block

In the i-th 4 × 4 block, "O" indicates the four coefficients of sub-block 1, and $E1_i$ denotes energy of sub-block 1, and the calculation method is shown in (2); "X" indicates the four elements of sub-block 2, and $E2_i$ denotes energy of sub-block 2, and the calculation method is shown in (3); $W_{2\times i-1}$ can be embedded by using the relationship between $E1_i$ and $E2_i$, and the embedding method is shown in (4).

$$E1_i = \sum_{m=3}^{4}\sum_{n=1}^{2} e(m,n)_i \tag{2}$$

$$E2_i = \sum_{m=1}^{2}\sum_{n=3}^{4} e(m,n)_i \tag{3}$$

$$W_{2\times i-1} = \begin{cases} 1 & E2_i \ge E1_i \\ 0 & E2_i < E1_i \end{cases} \tag{4}$$

In the i-th 4 × 4 block, "Y" indicates the four elements of sub-block 3, and $E3_i$ denotes energy of sub-block 3, and the calculation method is shown in (5); "Z" indicates the four elements of sub-block 4, and $E4_i$ denotes energy of sub-block 4, and the calculation method is shown in (6); $W_{2\times i}$ can be embedded by using the relationship between $E3_i$ and $E4_i$, and the embedding method is shown in (7).

$$E3_i = \sum_{m=1}^{2}\sum_{n=1}^{2} e(m,n)_i \tag{5}$$

$$E4_i = \sum_{m=3}^{4}\sum_{n=3}^{4} e(m,n)_i \tag{6}$$

$$W_{2\times i}=\begin{cases}1 & E4_i \geq E3_i\\ 0 & E4_i < E3_i\end{cases} \tag{7}$$

As a result, 2 bits watermark can be embedded in each 4 × 4 block, and watermark capacity can be increased to 2 times in the same frequency region.

However, in the new algorithm, in each 4 × 4 block the number of modified data is 2 times of the number in the original algorithm and this will inevitably lead to the decline of image quality. To improve image quality of the watermarked image, this paper reduces the number of modified data: in each 2×2 sub-block only two coefficients are modified to embed watermark. Figure 5, shows the location of modified data in each 4 × 4 block.

Y_m	Y_m	O_m	O_m
Y	Y	O	O
X_m	X_m	Z_m	Z_m
X	X	Z	Z

Figure 5. The Location of Modified Data in each 4 × 4 Block

$W_{2\times i-1}$ can be embedded in sub-block 1 and sub-block 2, $E1_i$ and $E2_i$ can be calculated according to (2) and (3). When $W_{2\times i-1}=1$, to ensure $E2_i \geqslant E1_i+k$, and k is the strength of watermark, and if $E1_i$ and $E2_i$ cannot meet the demand, embedding rule is defined as follows:

$$\begin{cases} delta=(k+E1_i-E2_i)/2 \\ \sum_{m=3}^{4}\sum_{n=1}^{1}e(m,n)_i=\sum_{m=3}^{4}\sum_{n=1}^{1}e(m,n)_i-delta/4 \\ \sum_{m=1}^{2}\sum_{n=3}^{3}e(m,n)_i=\sum_{m=1}^{2}\sum_{n=3}^{3}e(m,n)_i+delta/4 \end{cases} \tag{8}$$

Delta is total value to modify in sub-block 1 and sub-block 2, and each sub-block has 4 coefficients, so each coefficient need to modify delta/4, To improve the image quality of the watermarked image, only two coefficients is modified to embed watermark in each 2×2 sub-block.

When $W_{2\times i-1}=0$, to ensure $E1_i \geqslant E2_i+k$, if $E1_i$ and $E2_i$ cannot meet the demand, embedding rule is defined as follows:

$$\begin{cases} delta=(k+E2_i-E1_i)/2 \\ \sum_{m=3}^{4}\sum_{n=1}^{1}e(m,n)_i=\sum_{m=3}^{4}\sum_{n=1}^{1}e(m,n)_i+delta/4 \\ \sum_{m=1}^{2}\sum_{n=3}^{3}e(m,n)_i=\sum_{m=1}^{2}\sum_{n=3}^{3}e(m,n)_i-delta/4 \end{cases} \tag{9}$$

$W_{2\times i}$ can be embedded in sub-block 3 and sub-block 4, $E3_i$ and $E4_i$ can be calculated according to (5) and (6). When $W_{2\times i}=1$, to ensure $E4_i \geqslant E3_i+k$, and if $E3_i$ and $E4_i$ cannot meet the demand, embedding rule is defined as follows:

$$\begin{cases} delta = (k + E3_i - E4_i)/2 \\ \sum_{m=1}^{2}\sum_{n=1}^{1} e(m,n)_i = \sum_{m=1}^{2}\sum_{n=1}^{1} e(m,n)_i - delta/4 \\ \sum_{m=3}^{4}\sum_{n=3}^{3} e(m,n)_i = \sum_{m=3}^{4}\sum_{n=3}^{3} e(m,n)_i + delta/4 \end{cases} \quad (10)$$

When $W_{2\times i}=0$, to ensure $E3_i \geqslant E4_i+k$, if $E3_i$ and $E4_i$ cannot meet the demand, embedding rule is defined as follows:

$$\begin{cases} delta = (k + E4_i - E3_i)/2 \\ \sum_{m=1}^{2}\sum_{n=1}^{1} e(m,n)_i = \sum_{m=1}^{2}\sum_{n=1}^{1} e(m,n)_i + delta/4 \\ \sum_{m=3}^{4}\sum_{n=3}^{3} e(m,n)_i = \sum_{m=3}^{4}\sum_{n=3}^{3} e(m,n)_i - delta/4 \end{cases} \quad (11)$$

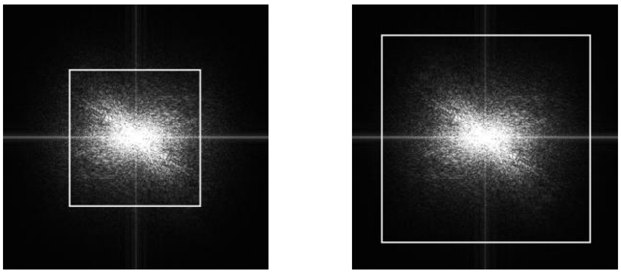
Using the proposed algorithm, watermark capacity can be increased to 2 times of the original algorithm in the premise of PSNR under the same. In 1/4-3/4 area, the watermark capacity limit is C_2 and the calculation method of C_2 is shown in (12):

$$C_2 = \frac{W/2}{4} \times \frac{H/4}{4} \times 2\ bit \quad (12)$$

For example, in a 512×512 image, the capacity limit is: C_2=((512/2)/4)×((512/4)/4)×2=4096bit; and in a 128×128 image, the capacity limit is: C_2=((128/2)/4)×((128/4)/4)×2=256bit. It can be seen watermark capacity is 2 times of the original algorithm.

3.3. Extend the Frequency Domain Region of Embedding Watermark

In the original algorithm, 1/4-3/4 area is selected to embedding watermark, and this paper extends the watermarked region to middle-high frequency region, such as: x: 1/8×width-7/8×width, y: 1/8×height-7/8×height, and this area will be referred to as 1/8-7/8 area in the following parts. Frequency amplitude images of Lena image are shown in Figure 6, and white line area shows the comparison of 1/4-3/4 area and 1/8-7/8 area.



（a）1/4-3/4 area （b）1/8-7/8 area

Figure 6. 1/4-3/4 Area and 1/8-7/8 Area in Frequency Amplitude Images

In 1/8-7/8 area, the watermark capacity limit is C_3 and the calculation method of C_3 is shown in (13):

$$C_3 = \frac{W \times 3/4}{4} \times \frac{H \times 3/8}{4}\ bit \quad (13)$$

For example, in a 512×512 image, the capacity limit: C_3=((512×3/4)/4)×((512×3/8)/4)=4608bit; and in a 128×128 image, the capacity limit: C_3 =((128×3/4)/4)×((128×3/8)/4)=288bit. Comparing with C1 and C3, it can be seen watermark capacity is increased in 1/8-7/8 area.

When embedding strength is 50000 and watermark capacity is 48 bits, we use Lena image and Elaine image as examples, and the watermark is embedded in 1/4-3/4 area and 1/8-7/8 area, and watermarked images are shown in Figure 7.

(a) Lena Embed in 1/4-3/4 Area (b) Lena Embed in 1/8-7/8 Area

(c) Elaine Embed in 1/4-3/4 Area (d) Elaine Embed in 1/8-7/8 Area

Figure 7. Watermarked Images in 1/4-3/4 Area and 1/8-7/8 Area

From Figure 7, it can be seen that the visual effect of watermarked image in 1/8-7/8 area is obviously better than the visual effect of watermarked image in 1/4-3/4 area. The reason is that when watermark is embedded in 1/8-7/8 area, the modified data is closer to high frequency region, and is further away from low frequency data, therefore the image quality is better.

However, if the watermarked region is too closer to high frequency region, the watermark is easily removed by low-pass filter, in this paper, some intermediate area is mainly considered: x:1/5×width-4/5×width, y:1/5×height-4/5×height，and this area will be referred to as 1/5-4/5 area in the following parts; x:1/6×width-5/6×width, y:1/6×height-5/6×height，and this area will be referred to as 1/6-5/6 area in the following parts.

Combining with the algorithm in 3.2, 2 bits watermark can be embedded in each 4×4 block, and the watermark capacity limit is C_4 in 1/5-4/5 area and the calculation method of C_4 is shown in (14):

$$C_4 = \frac{W \times 3/5}{4} \times \frac{H \times 3/10}{4} \times 2 \ bit \tag{14}$$

The watermark capacity limit is C_5 in 1/6-5/6 area and the calculation method of C_5 is shown in (15):

$$C_5 = \frac{W \times 2/3}{4} \times \frac{H \times 1/3}{4} \times 2 \ bit \tag{15}$$

Comparing (12),(14),(15), we can found that watermark capacity can be increased by embedding watermark in 1/5-4/5 area or 1/6-5/6 area. It can be seen when extending the frequency domain region of embedding watermark there are two advantages: (1) increasing watermark capacity; (2) improving visual effect of watermarked image.

4. Proposed Watermarking Scheme

In this paper, a novel efficient image watermark algorithm based on DFT transform is proposed. Firstly, the watermark information is encoded by using hybrid error correcting code, and the watermark is embedded into an image, and the code ensures that the correct rate of watermark extraction is 100% in the condition of the watermarked image under attacks. Secondly, through changing the way of embedding watermark into the frequency domain data block, watermark capacity can be increased to 2 times of the original algorithm. Thirdly, through extending the frequency domain region of embedding watermark, visual effect of the watermarked image is obviously improved and watermark capacity can be increased.

4.1. Watermark Embedding

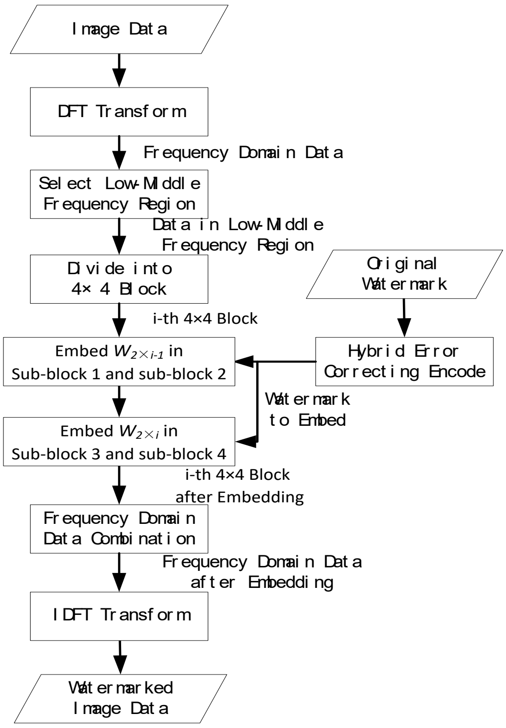


Figure 8. The Diagram of Watermark Embedding

The diagram of watermark embedding is shown in Figure 8, and the process of watermark embedding is described as follows:

(1) Getting image data after decoding an image file;

(2) Getting frequency domain data through the DFT transform of the image data;

(3) Selecting data area to embed watermark in the low-middle frequency region, and 1/4-3/4 area, 1/5-4/5 area and 1/6-5/6 area are considered, and it can be seen 1/5-4/5 area is the best area to embed watermark from analysis in part 5;

(4) The data in the low-middle frequency region is divided into 4×4 block;

(5) The watermark to embed is obtained after the original watermark information is encoded by using hybrid error correcting code which is defined in 3.1;

(6) $W_{2\times i-1}$ and $W_{2\times i}$ can be embedded in the i-th 4 × 4 block:

A. Embedding $W_{2\times i-1}$ in sub-block 1 and sub-block 2 by using (2), (3), (8), (9) which are defined in 3.2;

B. Embedding $W_{2\times i}$ in sub-block 3 and sub-block 4 by using (5), (6), (10), (11) which are defined in 3.2;

(7) Frequency domain data after embedding watermark is obtained through combining every 4×4 blocks into the original frequency domain data;

(8) Achieving watermarked image data through the IDFT transform of the frequency domain data.

4.2. Watermark Extraction

The diagram of watermark extraction is shown in Figure 9, and the process of watermark extraction is described as follows:

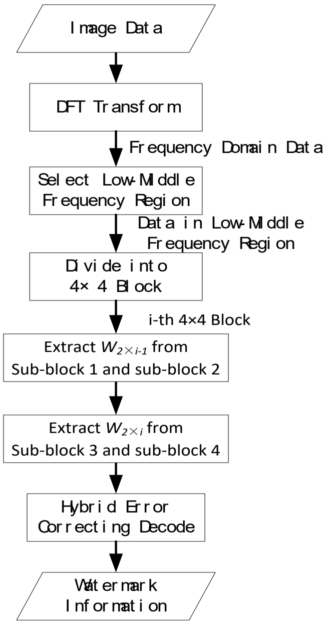


Figure 9. The Diagram of Watermark Extraction

(1) Getting image data after decoding an image file;

(2) Getting frequency domain data through the DFT transform of the image data;

(3) Selecting data area to extract watermark in the low-middle frequency region, and this area must be consistent with the area to embed watermark.

(4) The data in the low-middle frequency region is divided into 4×4 block;

(5) $W_{2\times i-1}$ and $W_{2\times i}$ can be extracted in the i-th 4 × 4 block:

A. Extracting $W_{2\times i-1}$ from sub-block 1 and sub-block 2 by using (2), (3), (4) which are defined in 3.2;

B. Extracting $W_{2\times i}$ from sub-block 3 and sub-block 4 by using (5), (6), (7) which are defined in 3.2;

(6) The final watermark information is obtained through the extracted watermark is decoded by using hybrid error correcting code which is defined in 3.1.

5. Experimental Results and Performance Analysis

In this paper, 4 128×128 images in USC-SIPI image database is used as a test set, and the length of the original watermark is 64 bits, and after the original watermark is encoded through hybrid error correcting code which is defined in 3.1, the length of the watermark to embed is 138 bits.

5.1. Transparency

Using the proposed algorithm, the 138 bits watermark is embedded in 1/4-3/4 area, 1/5-4/5 area and 1/6-5/6 area separately, and using the original algorithm, the 64 bits watermark is embedded in 1/4-3/4 area, PSNR statistical results of 4 cases are shown in Figure 10:

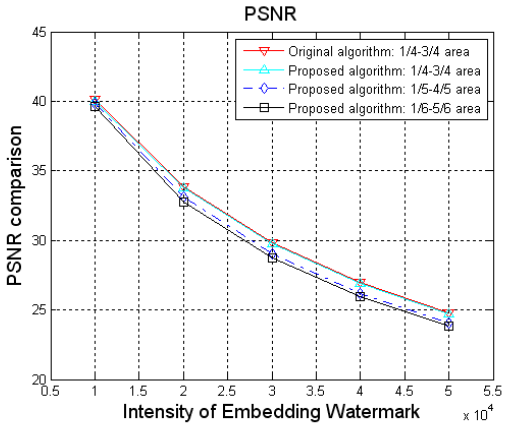
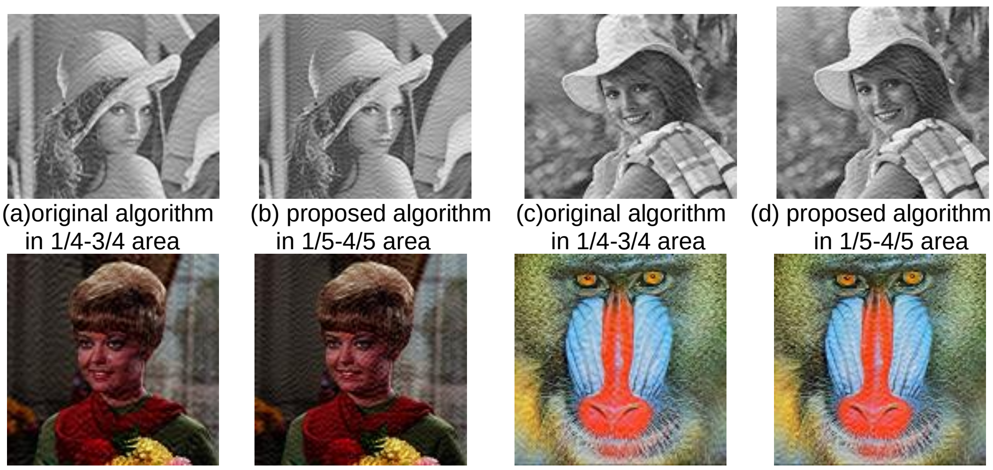


Figure 10. PSNR Statistical Results of Proposed Algorithm and Original Algorithm

From Figure 10, it can be seen that using the proposed algorithm, the length of the watermark to embed is more than 2 times of the length of the original watermark, but PSNR of the proposed algorithm and PSNR of the original algorithm are basically the same. When embedding strength is 30000, we use Lena, Elaine, Girl and Mandrill as examples, and watermarked images after embedding watermark using the proposed algorithm and the original algorithm are shown in Figure 11.



(a)original algorithm in 1/4-3/4 area
(b) proposed algorithm in 1/5-4/5 area
(c)original algorithm in 1/4-3/4 area
(d) proposed algorithm in 1/5-4/5 area
(e)original algorithm in 1/4-3/4 area
(f) proposed algorithm in 1/5-4/5 area
(g)original algorithm in 1/4-3/4 area
(h) proposed algorithm in 1/5-4/5 area

Figure 11. Watermarked Images Using Proposed Algorithm and Original Algorithm

From Figure 11, it can be seen that the image effect using the proposed algorithm in 1/5-4/5 area is better than using the original algorithm.

In summary, the proposed algorithm and the original algorithm are basically the same in PSNR, and the proposed algorithm is better than the original algorithm in visual effect of watermarked image.

5.2. Robustness

When embedding strength is 30000, watermarked image is suffered with 5 kinds of attacks, and calculating bit error rate (BER) after extracting the watermark, and statistical results are shown in Table I.

Table I. BER (%) Against Attacks

attack		original algorithm	proposed algorithm		
type	parameter	1/4-3/4 area	1/4-3/4 area	1/5-4/5 area	1/6-5/6 area
JPEG code	40%	0	0.0625	0	0
	20%	0	0.0156	0	0
	10%	0	0.0625	0	0
Crop (crop area: 9/32)	Left and Top	0.03125	0.0781	0	0
	Right and Bottom	0.03125	0.0625	0	0
Line	5 lines	0.0625	0.0625	0	0
Resolution	80%	0	0.0625	0	0
	90%	0	0.0625	0	0
	125%	0	0.0625	0	0
Rotate	-10^o	0.0468	0.0468	0	0
	-6^o	0.0156	0.0156	0	0
	-2^o	0.0312	0.0625	0	0.0468
	2^o	0.0312	0.0781	0	0.0312
	6^o	0.0312	0.1093	0	0
	10^o	0.0625	0.0156	0	0

It can be seen from Table I, that the proposed algorithm has excellent robustness against JPEG coding attack, crop attack, line attack, resolution attack and rotation attack, and when embedding watermark in 1/5-4/5 area, the correct rate of watermark extraction is 100%.

In summary, the proposed algorithm is significantly better than the original algorithm in robustness, and it is able to ensure that the correct rate of extraction is 100% after the watermarked image under attacks.

6. Conclusions

In this paper, a novel efficient image watermark algorithm based on DFT transform is proposed. Firstly, the watermark information is encoded by using hybrid error correcting code, and the watermark is embedded into an image, and the code ensures that the correct rate of watermark extraction is 100% in the condition of the watermarked image under attacks. Secondly, through changing the way of embedding watermark into the frequency domain data block, watermark capacity can be increased to 2 times of the original algorithm. Thirdly, through extending the frequency domain region of embedding watermark, visual effect of the watermarked image is obviously improved and watermark capacity can be increased. The experimental results show that the proposed algorithm is significantly better than the original algorithm in robustness, and it is able to ensure that the correct rate of watermark extraction is 100% after the watermarked image under attacks, and the proposed algorithm and the original algorithm are basically the same in

PSNR, and the proposed algorithm is better than the original algorithm in visual effect of watermarked image.

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References

[1] T. Jayamalar and V. Radha, "Survey on Digital Video Watermarking Techniques and Attacks on Watermarks", International Journal of Engineering Science and Technology, vol. 2, vol. 12, **(2010)**, pp. 6963-6967.
[2] E. T. Lin and E. J. Delp, "A review of data hiding in digital images", Proceedings of the conference on Image processing, vol. 4, **(1999)**, pp. 274-278
[3] D. He, Q. Sun and Q. Tian, "An Object Based Watermarking Solution For Mpeg4 Video Authentication", ICASSP, **(2003)**, pp. 537-540
[4] S. Pereira, J. J. K. O. Ruanaidh and F. Deguillaume, "Template Based Recovery of Fourier-Based Watermarks Using Log-polar and Log-log Maps", Conf on Multimedia Computing and Systems (ICMCS'99), Italy, **(1999)**, vol. 6.
[5] X. Y. Wang, C. P. Wang, H. Y. Yang and P. P. Niu, "A robust blind color image watermarking in quaternion Fourier transform domain", The Journal of Systems and Software, vol. 86, pp. 255-277, **(2013)** Febuary.
[6] X. Y. Wang, P. P. Niu, L. Meng and H. Y. Yang, "A robust content based image watermarking using local invariant histogram", Multimedia Tools and Applications, vol. 54, **(2011)** August, pp. 341-363,.
[7] G. C. Langelaar and R. L. Lagendijk, "Optimal Differential Energy Watermarking of DCT Encoded Images and Video", IEEE TRANSACTIONS ON IMAGE PROCESSING, vol. 10, no. 1, **(2001)**, pp. 148-158
[8] Y. G. DU, A. N. CAI and J. O. SUN, "DCT-based Video Watermark Technique Using Downsampling", ACTA ELECTRONICA SINICA, vol. 33, no. 12, **(2005)** December, pp. 2219-2221.
[9] L. Lianshan and L. Renhou, "Blind Video Watermark Scheme Based on Direct Current Component in Discrete Cosine Transformation Domain", JOURNAL OF XI'AN JIAO TONG UNIVERSITY, vol. 40, no. 4, **(2006)** April, pp. 402-405.
[10] Q. Jianjun, "Research of Digital Video Watermark Technology", Chang Sha: Hunan Normal University, **(2010)**.
[11] C. Junmei, "A Robust Digital Watermark Algorithm Base on DCT", Microcomputer Applications vol. 16, no. 1, **(2010)**, pp. 11-12.
[12] W. H. Lin, Y. R. Wang, S. J. Horng, T. W. Kao and Y. Pan, "A blind watermarking method using maximum wavelet coefficient quantization", Expert Systems with Applications, vol. 36, **(2009)** November, pp. 11509–11516.
[13] L. Ghouti, A. Bouridane, M. K. Ibrahim and S. Boussakta, "Digital Image Watermarking Using Balanced Multiwavelets", IEEE TRANSACTIONS ON SIGNAL PROCESSING, vol. 54, **(2006)** April, pp. 1519–1536.
[14] M. Barni, F. Bartolini and A. Piva, "Improved Wavelet-Based Watermarking Through Pixel-Wise Masking", IEEE TRANSACTIONS ON IMAGE PROCESSING, vol. 10, no. 5, **(2001)** May, pp. 783-791.
[15] N. Leelavathy, E. V. Prasad, S. S. Kumar and B. C. Mohan, "Oblivious image watermarking in discrete multiwavelet domain using QIMM", Journal of Multimedia(JMM), vol. 6, no. 4, **(2011)**, pp. 359-368.
[16] A. A. Reddy and B. N. Chatterji, "A new wavelet based logo-watermarking scheme", Pattern Recognition Letters, vol. 26, **(2005)** May, pp. 1019-1027.
[17] R. M. Shen, Y. G. Fu and H. T. Lu, "A novel image watermarking scheme based on support vector regression", The Journal of Systems and Software, vol. 78, no. 1, **(2005)** October, pp. 1-8.
[18] A. Aung, B. P. Ng and S. Rahardja, "A Robust Watermarking Scheme Using Sequency-ordered Complex Hadamard Transform", Journal of Signal Processing Systems, vol. 64, no. 3, **(2011)** September, pp. 319-333.
[19] H. Luo, F. X. Yu, Z. L. Huang and Z. M. Lu, "Blind image watermarking based on discrete fractional random transform and subsampling", International Journal for Light and Electron Optics, vol. 122, no. 4, **(2011)** Febuary, pp. 311–316.

[20] X. Gao, C. Deng, X. Li and D. Tao, “Geometric Distortion Insensitive Image Watermarking in Affine Covariant Regions”, IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART C: APPLICATIONS AND REVIEWS, vol. 40, no. 3, **(2010)** MAY, pp. 278 - 286.
[21] J. S. Seo and C. D. Yoo, “Image Watermarking Based on Invariant Regions of Scale-Space Representation”, IEEE TRANSACTIONS ON SIGNAL PROCESSING, vol. 54, no. 4, **(2006)** APRIL, pp. 1537-1549.

Author

Hai-yang Ding, received his M.S. degree in signal and information processing from Beijing Jiaotong University, Beijing in 2004, and his B.S. degree in electronics and information technology from Beijing Jiaotong University, Beijing in 2001. He is currently a Ph.D. candidate at Beijing University of Posts and Telecommunications, Beijing, China. His current research interests include information security, digital image processing, DSP technology.