

A Dynamic Multiple Watermarking Algorithm Based on DWT and HVS

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Received June 14, 2012; revised July 31, 2012; accepted August 12, 2012

ABSTRACT

In this paper, a dynamic robust multiple watermarking algorithm is proposed based on Discrete Wavelet Transform (DWT) and Human Visual System (HVS). Watermark image is transformed by Arnold transform. Original image is divided into blocks with 8 by 8 and each block is transformed by DWT. By adopting the Just Noticeable Difference (JND) of HVS and changing low frequency coefficients, binary string message can be embedded into the decomposed original image. Watermark can be extracted blindly. Experimental results have shown that the proposed watermarking has robust against many attacks such as JPEG compressing, cropping, additive noise, line removal, median filter and related attacks with sinStirMark.

Keywords: Dynamic Multiple Watermarking; JND

1. Introduction

Digital watermarking is a new technology of information hiding and it has effective effect for Copyright Protection. The conception of digital watermarking appeared firstly in the conference of image processing in 1994. Many experts made a lot of research for digital watermarking based on spatial [1] and transform domain [2,3].

From the view of image processing, embedding watermark information can be seemed that a puny signal overlap in a strength signal. Human will not feel the existence of information if the embed strength is lower than the threshold of HVS [4,5].

Robustness of watermarking is important for many applications. Compared with spatial domain methods, transform domain methods have stronger robust. Watermarking based on DWT [6] is an important transform domain method. Compared with the Discrete Cosine Transform (DCT), DWT has a better performance. Firstly, it has good time-frequency decomposition in accordance with the characteristic of HVS. Moreover, DWT has good compatibility for JPEG compression. Embedding watermark information in the DWT domain [7] has better robust against JPEG compression.

In this paper, an algorithm for data hiding by using DWT and JND model of HVS is proposed. It is a dynamic multiple blind watermarking algorithm, since more than one watermarks can be embedded into the original image. Original image is divided into 8*8 blocks

and each block is transformed by DWT. A visual model [8] is used to calculate JND threshold. Watermark can be embedded by changing the LL-coefficient of original image.

The paper is organized as follows: Related work is introduced in Section 2. In Section 3 the proposed watermarking algorithm is discussed in detail. Section 4 is experimental results and at last conclusions are drawn.

2. Related Work

JND is defined as a measure referring to the capability of a human observer to detect noise or distortion in the field of view. It is related to characteristics of HVS and adaptive to contents of visual signal under consideration. With a HVS model, accessory information can be embedded in the regions with the least HVS sensitivity to the incurred changes. JND model in the essay of Podilchuk [9] is used. Original image of size $M \times N$ is first divided into 8×8 blocks (B_m) and each block is decomposed by DWT (B'_m). The formula is as follow:

$$B_m = f_m(x, y), m = 1, 2, \dots, (M/8) * (N/8) \quad (1)$$

$$B'_m = \text{DWT}(B_m) = F_m(x, y) \quad (2)$$

Contrast sensitivity can be calculated in DWT domains by the formula following:

$$C(u, v) = 5.05e^{-0.178(u+v)}(e^{0.1(u+v)} - 1) \quad (3)$$

where u, v is frequency. Noise sensitive visual can be calculated by using Contrast Sensitivity. The formula is as follow:

$$S_{\text{DWT}} = \sum_{\forall(u,v)} C(u,v) \left| F_{\text{DWT}(u,v)} \right|^2 \quad (4)$$

where F_{DWT} is DWT of each block. JND can be calculated by:

$$\text{JND} = \alpha \ln S_{\text{DWT}} \quad (5)$$

where α is strength which can be obtained by experiment.

3. Proposed Watermarking Algorithm

Original image is decomposed into four sub-band images by DWT. Approximate sub-image (LL) is stable since it contains the majority of image energy. In order to gaining a better robustness, the watermark is embedded into approximate sub-image.

3.1. Watermark Embedding Process

By altering coefficients of approximate sub-image blocks, watermark is embedded. Watermark embedding is implemented through the following procedures.

Step 1: Generate watermark

In our scheme, two binary images are used as original watermarks W . It is transformed into W' by Arnold transform. W' is scanned on-line and then transformed into one-dimensional sequence

$W_m = \{w_j | w_j \in \{0,1\}, j = 1, 2, \dots, K\}$, where K is the number of watermark sequence. Two watermarks are considered for embedded labeled as watermark1 W_{m1} and watermark 2 W_{m2} .

Step 2: Divide original image

Original image of size $M \times N$ is divided into 8×8 blocks which are scanned into one-dimensional horizontal blocks (B_k).

Step 3: Calculate JND

JND calculation for the coefficient in the low-frequency domains can be finished according to the Formula (5).

Step 4: Generate number sequence

Put a secure key X into a random number generator to produce random number sequence I .

$I(i) \in \{1, 2, \dots, (M \times N)/64\}$, if $i = k$, then $I(i) = I(k)$.

Step 5: choose image blocks to be embedded

Transform each block into DWT coefficient matrix block $B_k(u, v)$. Sub-block $B_{I(i)}(u, v)$ is selected to embed W'_{i1} and $B_{I(i)}(u, v)$ is selected to embed W'_{i2} .

Step 6: Embed Watermarking

Let $D_k(u, v)$ denotes LL sub-band coefficient of sub-block B_k , Coefficients $D_k(1, 2)$ and $D_k(4, 3)$ are selected to be embedded. Embedding rule is:

If $W_{ik} = 1 (k = 1, 2)$ and $D_k(1, 2) \geq D_k(4, 3)$, exchange coefficients of $B_k(1, 2)$ and $B_k(4, 3)$. Else if $W_{ik} = 0 (k = 1, 2)$ and $D_k(1, 2) < D_k(4, 3)$, exchange coefficients of $B_k(1, 2)$ and $B_k(4, 3)$.

Embedding is done as Equations (6) and (7):

If $W_{mk} = 1 (k = 1, 2)$ and $D > 0$

$$\left. \begin{aligned} D'_k(1, 2) &= D_k(1, 2) + D/2 + D/4 \\ D'_k(4, 3) &= D_k(4, 3) - D/2 - D/4 \end{aligned} \right\} \quad (6)$$

where $D = \text{JND}_k - D(1, 2) + D(4, 3)$.

If $W_{mk} = 0 (k = 1, 2)$ and $D > 0$

$$\left. \begin{aligned} D'_k(1, 2) &= D_k(1, 2) - D/2 - D/4 \\ D'_k(4, 3) &= D_k(4, 3) + D/2 + D/4 \end{aligned} \right\} \quad (7)$$

where $D = \text{JND}_k - D(4, 3) + D(1, 2)$.

Where JND_k is JND value of $D_k(u, v)$. W_{mk} is watermarking signals.

Step 7: Obtain watermarked image

Inverse DWT(IDWT) is applied to obtain the watermarked image I' .

Watermark embedding procedure is shown in **Figure 1**.

Step 8: Dynamic watermark embedding

By using the same watermark Embedding process as Step 1 - Step 7, more than one watermarks can be embedded into original image at any time, which can achieve the dynamic watermarking embedding.

3.2. Watermark Extraction Process

Watermark can be extracted blindly without original image. The steps are as follows.

Step 1: Apply DWT

Divide watermarked image I' into 8×8 sub-blocks. Each block is scanned and sorted as embedding process. DWT is done to obtain decomposed sub-block $\tilde{B}_k(u, v)$.

Step 2: Regenerate number sequences

Regenerate number sequences using the same key to select $\tilde{B}_k(u, v)$.

Step 3: Extract Watermark

Let $\tilde{D}_k(u, v)$ denotes LL sub-band coefficient of sub-block \tilde{B}_k . Extract the one-dimensional sequence \tilde{W} as:

$$\tilde{W} = \begin{cases} 1, & \text{if } \tilde{D}_k(1, 2) \geq \tilde{D}_k(4, 3) \\ 0, & \text{if } \tilde{D}_k(1, 2) < \tilde{D}_k(4, 3) \end{cases} \quad (8)$$

Step 4: Obtain the perfect watermarks

Transform \tilde{W} into two-dimensional watermark image. The perfect watermarks are obtained after Arnold transform.

Watermark Extraction process procedure is shown in **Figure 2**.

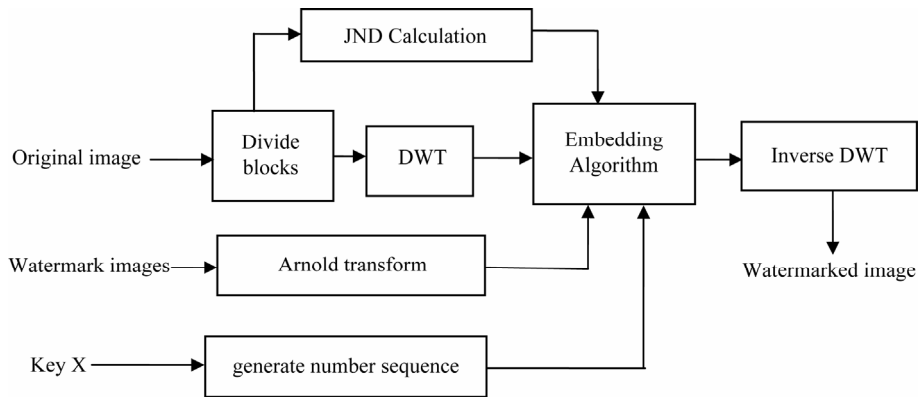


Figure 1. Watermark embedding procedure.

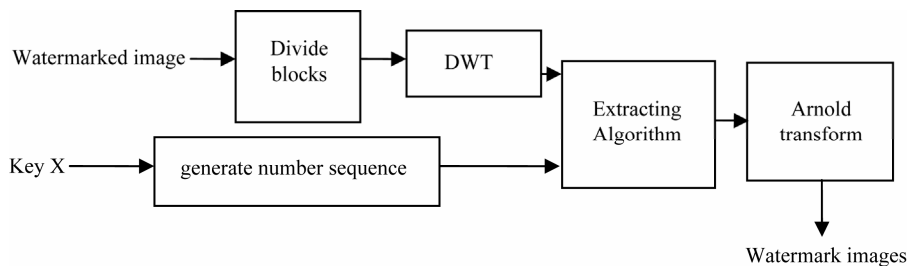


Figure 2. Watermark embedding procedure.

4. Experimental Results

Experimental results are simulated by programming in Matlab. Different cover images are used as original images and two binary watermark images for the test. Experimental results with 256×256 of original Lena image are given. Original image and watermark images are shown in the Figure 3. Embedded and extracted watermarks are shown in the Figure 4.

4.1. Robustness

This section examines the robustness against some attacks. Normative Correlation (NC) is employed to measure the similarity of extracted and original watermark defined as:

$$NC(W, W') = \frac{\sum_{i=1}^M \sum_{j=1}^N W(i, j)W'(i, j)}{\sqrt{\sum_{i=1}^M \sum_{j=1}^N W^2(i, j)} \sqrt{\sum_{i=1}^M \sum_{j=1}^N W'^2(i, j)}} \quad (9)$$

where W is original watermark and W' is extracted watermark with size $M \times N$. The bigger NC is, the better similarity between W and W' is.

Performance analysis results are cited in Table 1. The proposed method is compared to the method of Reference [10] based on DCT and HVS. From the Table 1 we see that the proposed method performs well against JPEG compression with quality factor of 40, the quality

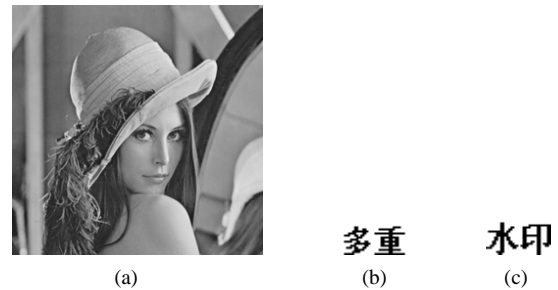


Figure 3. (a) Original image; (b) Watermark 1; (c) Watermark 2.

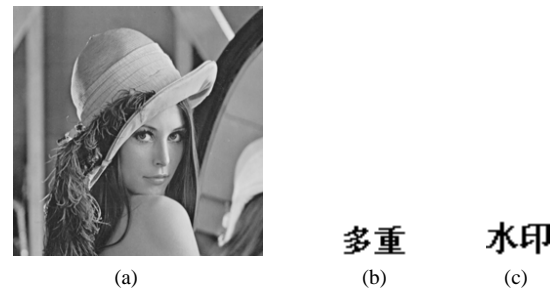





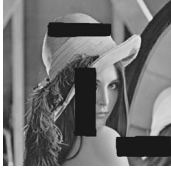




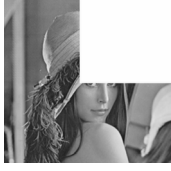









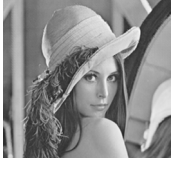
















Figure 4. (a) Watermarked image; (b) Extracted watermark 1; (c) Extracted watermark 2.

of the extracted watermarks are good, this performance is better than the method in [10]. To demonstrate proposed method resistance to noise, gaussian noise was added. The experimental results in Table 1 show that the algorithm can resist this noise attack very well. It can also be

Table 1. The performance results for the proposed method and the method in [10].

Attacks	Attacked watermarked image	Proposed method		Method in [10]	
		Extracted watermark 1	Extracted watermark 2	Extracted watermark 1	Extracted watermark 2
JPEG (Q = 40)					
Painting					
Crop in the upper right corner 1/4					
Gaussian noise (2%)					
Line removal					
Histogram equalization					
Median filtering (3 × 3)					

observed from **Table 1** that the proposed method outperforms in many cases. The proposed method provides better results in painting, line removal, histogram equalization, median filtering and cropping attack.

4.2. Invisibility

Peak signal noise ratio (PSNR) is used to evaluate the

invisibility which is given in Equation (10):

$$\text{PSNR} = 10 \times \lg \left(\frac{255^2}{\text{MSE}} \right) \quad (10)$$

$$\text{MSE} = \frac{1}{M \times N} \sum_{i=1}^N \sum_{j=1}^M [I(i, j) - I'(i, j)]^2$$

where $I(i, j)$ and $I'(i, j)$ stand for the pixel values of

Table 2. PSNR values of proposed method with different original image (db).






Watermarked image					
	Lena	Cameraman	Sailboat	Peppers	Barbara
PSNR	41.26	37.39	38.41	36.70	38.19

Table 3. Comparison between the proposed scheme and the scheme of reference [10].

Attacks	The proposed scheme			Reference scheme [10]		
	PSNR	NC1	NC2	PSNR	NC1	NC2
No attack	39.973	1	1	38.384	1	1
JPEG (Q = 40)	39.376	0.927	0.935	35.512	0.833	0.820
Painting	30.901	0.953	0.954	30.534	0.905	0.896
Crop in the upper right corner 1/4	33.316	0.871	0.828	33.005	0.783	0.775
Gauss noise (2%)	36.958	0.923	0.942	35.571	0.881	0.894
Line removal	38.709	0.949	0.944	37.631	0.793	0.752
Histogram equalization	20.69	0.930	0.927	16.69	0.765	0.716
Median filtering (3 × 3)	39.554	0.873	0.869	39.017	0.631	0.627

original and watermarked image respectively. M and N are height and width of image.

Table 2 shows PSNR of the proposed scheme for different watermarked images. **Table 3** represents PSNR of watermarked attacked images and NC values of extracted watermark1 and extracted watermark 2 between the proposed method and the method of Reference [10].

5. Conclusion

In this paper, an effective robust dynamic multiple blind watermarking algorithm is presented based on DWT domain. Robust is guaranteed because watermark is embedded into low-frequency with JND model of DWT. Experiment results show that the watermark algorithm can provide a high tolerance to noise, compression, cropping, painting, histogram equalization, filtering, noise attacks. Compared with the scheme of Reference [9], our method shows greater robustness against these attacks.

6. Acknowledgements

This work is partly supported by Shenzhen Internet industry to develop special fund (C201005250085A) and National Nature Science Foundation of China (Grant NO.61005049).

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