# A Novel Digital Watermark Based on Wavelet Coefficients Comparison

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**Summary**
Watermark technology is one of the most promising and effective ways for copyright protection of digital media and safe transmission of digital information. In the proposed method, the watermark is embedded in the components of medium frequency on the horizontal and vertical direction based on the wavelet coefficients comparison, and an effective strategy of parameter adjustment is used to reduce the error occurred in the traditional method. Then the attack testes are completed in the environment of MATLAB 7.0. The results indicate that the presented method performs good robustness in addition to holding the image quality under the noise attack, filtering and image cutting etc..

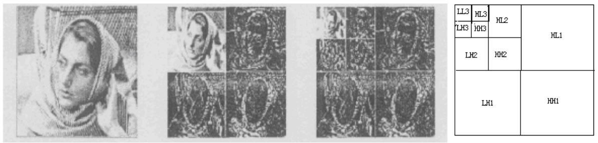
***Key words:***
*Digital watermark, wavelet, coefficients comparison.*

## 1. Introduction

With the popularization of internet, the security problem of digital information is becoming increasingly important. With the help of digital camera, printer and even the cell phone, nowadays people can quickly transmit the digital information to every place of the world conveniently. For instance, we can achieve issuing work, transmitting information and remote education in the internet. In this condition, the digital information works will face sever challenge of illegal infringement, copyright piracy and malicious tempering[1]. In order to address these problems, many strategies were proposed in recent years, such as encoding, digital signature, digital label and digital watermark [2-4].
In recent years, the Watermark technology based on transform field method is consider one of the promising and effective way for copyright protection and safe transmission of digital information because of its robust characteristic, and its suitability on the international standard of image and video.

## 2. Wavelet Transform

The basis theory of wavelet transform [5] is that the signal in $L^2(R)$ is approximated and presented by a series of base functions, known as wavelet function which is constructed through the translation and stretch of a basis wavelet function in different scale. For two-dimensional image signal, after discrete wavelet transform(DWT) of the first order, it will be extracted into four sub-images, and each sub-image has quarter size of original image. The four sub-images include the approximate sub-image of low frequency denoted as LL1, the horizontal detail sub-image named as HL1 and vertical sub-image named as LH1 and the diagonal detail sub-image HH1. Subsequently, LL1 can be extracted into the sub-images of the next order in the same way. Repeating this sequence, the multi-level wavelet transform of the image can be achieved, accordant with the human visual characteristic.



(a)Original image (b) 1 order WT (c)2 order WT (d)3 order WT

Fig. 1 Proposed beam former.

## 3. Novel Algorithm Based on Wavelet Coefficient Comparison

### 3.1 Embedding of digital watermark

Let the original image is gray image with size of M×N, expressed as following equation:

$$I = \{I_{i,j}, 1 \le i \le M, 1 \le j \le N\} \quad (1)$$

Suppose the original watermark image W is binary image with size of m×n, expressed as following equation:

$$W = \{w_{i,j}, 1 \le i \le m, 1 \le j \le n\} \quad (2)$$

Where:

$$m \le M/2, n \le N/2 \quad (3)$$

The embedded steps are described as below：
Stepl: If the watermark image is not binary image, it will be binarized firstly and then the hidden image w is obtained after it is scrambled with the Arnold transform[5]。

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Step2: Completing the wavelet transform of the gray image at the first order. And LL1, HL1, LH1 and HH1 will be obtained by following equation:

$$[LL1,HL1,LH1,HH1]=dwt2(I,'haar') \quad (3)$$

Where dwt2 means two-dimensional wavelet transform using harr wavelet base. HL1 and LH1 are selected to embed hidden information.

Step3: Embedding the hidden information. HLl is a two-dimension matrix and it will be decomposed into a serial of ordered pairs $S_{i,j}$, denoted as:

$$S_{i,j} = \{< a_{i,j}, b_{i,j} > \cdot | 1 \le i \le M, 1 \le j \le N/2\} \quad (4)$$

The embedding rule of the hidden image is described as below.

According to the relationship between $a_{i,j}$ and $b_{i,j}$ in each ordered pair $< a_{i,j}, b_{i,j} >$, it represents 0 or 1. If $a_{i,j} > b_{i,j}$, the ordered pair represents l, and if $a_{i,j} < b_{i,j}$, it represents 0. Also, each ordered pair in each row of HL1 is corresponded to a value of the odd column in each row of the hidden image $W$. It means that if $W_{i,j}$ is 1, let $a_{i,j} > b_{i,j}$, and if $W_{i,j}$ is 0, let $a_{i,j} < b_{i,j}$. When the relationship between $a_{i,j}$ and $b_{i,j}$ in each ordered pair $< a_{i,j}, b_{i,j} >$ is not correspondent with the value of $W_{i,j}$, $a_{i,j}$ is put to $b_{i,j}$, that means $b_{i,j}$ is equal to $a_{i,j}$. Then adjust the value of $b_{i,j}$ according to the relative value of $W_{i,j}$, in which when $W_{i,j}$ is 1, $b_{i,j}$ is subtracted a value x1 so that the equation $a_{i,j} > b_{i,j}$ is satisfied, when $W_{i,j}$ is 0, $b_{i,j}$ is added a value x1 so that let the equation $a_{i,j} < b_{i,j}$ is satisfied.

With the same way, the even column in hidden image $W$ is embedded to LH1. After embedding the information, HL1 is expressed as HL1' and LH1 is expresses as LH1'.

Step4: Achieving the inverse wavelet transform with LL1, LH1', HL1' and HH1.

$$I'=idwt2(LL1,\ HL1',\ LH1',\ HH1,\ haar) \quad (5)$$

## 3.2 Extraction of digital watermark

Step1: Completing the wavelet transform of I' carrying with embedded hidden image, denoted as:

$$[LL1e,HL1e,LH1e,HH1e]=dwt2(I','haar') \quad (6)$$

Where HL1e and LH1e are selected to extract the hidden information.

Step2: Extracting the hidden information from HLle. This process is the inverse process of embedding hidden information. HLle is decomposed into a serial of ordered pairs $S_{i,j}$, denoted as::

$$S_{i,j} = \{< a_{i,j}, b_{i,j} > \cdot | 1 \le i \le M, 1 \le j \le N/2\} \quad (7)$$

Then the hidden image $\overline{W}$ is extracted according following regulations.

When $a_{i,j} < b_{i,j}$, let $\overline{W}_{i,j}$ =0 and when $a_{i,j} > b_{i,j}$, let $\overline{W}_{i,j}$ =1. The odd columns of hidden image $\overline{W}$ are extracted from HL1e. With the same method, the even columns of $\overline{W}$ are extracted from LH1e.

Step3: Achieving the inverse scrambling. According the key k (scrambling times), the extracted hidden image $\overline{W}$ is restored to $W$ using Arnold transform algorithm. Suppose the scrambling cycle is T. When k<T, the restoring times is (T-k). When k>T, the restoring times is T-(k mod T).

## 4. Simulation and Results Analysis

### 4.1Test without attack

In Matlab7.0, the traditional Lena image (384×384) is selected as the carrier image and the binary image "CQUC" (64×64) is the watermark, shown in Fig.2(a) and Fig.3(a). The scrambled image is shown in Fig.3(b). After embedding the scrambled watermark image, the result is shown in Fig.2(b).

(a)Carrier image (b) Embedding result

Fig.2 Carrier image and its result after embedding


(a)Watermark (b)Scrambled result (c)Extracted result(d)Restoring result

Fig.3 Carrier image and its result after embedding

From Fig.2, it is seen that the difference between original carrier image and its embedding result image can not be identified by human visual system. It means the algorithm has good subjective effect. From Table 1, it is indicated that the novel algorithm has the significant transparency

because the PSNR is much larger than 30. Further more, the value of NC indicates that the extract watermark is as almost same as the original watermark objectively.
Compared with the traditional method, the transparency and similarity are both enhanced significantly in the novel algorithm.

Table 1: Extracted results comparison

| *Algorithm* | *PSNR(dB)* | *NC* |
|---|---|---|
| Traditional | 44.451 | 0.98219 |
| Novel | 46.729 | 0.98992 |

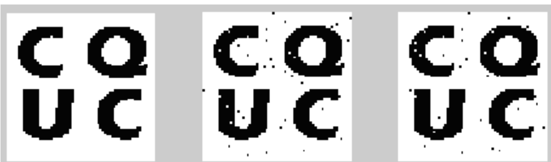
## 4.2 Attack test

### 4.2.1 Brightness, contrast and histogram equalization

The attacks of brightness and contrast increasing and decreasing are put to the carrier image with embedded watermark. The results are shown in Fig.4, Fig.5 and Table 2.

(a)Carrier image (b) Brightness increasing (c) Brightness decreasing

Fig.4 Attack of brightness and contrast



(a)Watermark (b) Watermark of BrS (c) Watermark of BrD

Fig.5 Extracted results after attack

Table 2: Extracted results comparison

| *Attack Type* | *PSNR(dB)* (traditional) | *PSNR(dB)* (novel) | *NC* (traditional) | *NC* (novel) |
|---|---|---|---|---|
| BrS | 13.5028 | 14.066 | 0.98185 | 0.9905 |
| BrD | 22.1054 | 22.114 | 0.98589 | 0.9946 |
| CrS | 14.9608 | 15.105 | 0.97681 | 0.9788 |
| CrD | 22.9637 | 22.946 | 0.98263 | 0.9905 |
| HgE | 18.684 | 19.381 | 0.86996 | 0.9220 |

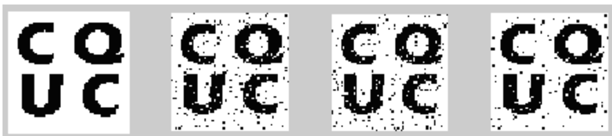
In Fig.5 and Table 2, BrS represents the brightness increasing, BrD represents the brightness decreasing, CrS represents the contrast ratio increasing and CrD represents the contrast ratio decreasing. Also he represents the attack of histogram equalization.
After these strong attacks, the image quality becomes deteriorated seriously and the Signal to Noise Ratio(SNR) is very low. But the watermark can be extracted reliably. It indicates that the novel algorithm has the strong capacity to the attack of brightness and contrast change. Especially, under the attack of histogram equalization, the robust of the novel algorithm is enhanced significantly compared with the traditional method.

### 4.2.2 Noise attack

The attacks of adding Gauss noise, salt noise and multiplicative noise are put to the carrier image with embedded watermark. The test results are shown in Fig.6 and Fig.7. The PSNRs and NC results are shown in Table 3.
In Fig.7 and Table 3, Gauss represents the attack of adding Gauss noise, Salt represents the attack of adding salt noise, and Multi represents adding the multiplicative noise.

(a)Carrier image (b) Gauss noise (c) Salt noise (d)Multiplicative

Fig.6 Attack of different noise



(a)Watermark (b) Result of Gauss (c) Result of Salt (d) Result of Multi

Fig.7 Extracted results after noise attack

Table 3: Extracted results comparison

| *Noise Type* | *PSNR(dB)* (traditional) | *PSNR(dB)* (novel) | *NC* (traditional) | *NC* (novel) |
|---|---|---|---|---|
| Gauss | 43.3947 | 45.093 | 0.89886 | 0.9559 |
| Sault | 25.562 | 25.647 | 0.94288 | 0.9566 |
| Multi | 44.1225 | 46.076 | 0.95329 | 0.9758 |

From the results, it is seen that the robust of the novel algorithm is increased significantly. Especially, under the attack of Gauss noise, the robust of the novel algorithm is enhanced sharply compared with the traditional method. In the mean time, the proposed algorithm also has the stronger capacity against the attack of salt noise.

## 5. Conclusions

On the basis of the traditional method of coefficient comparison, a novel algorithm is proposed to improve the error of coefficients adjustment. And several attack tests are achieved to prove the robust and transparency of the proposed algorithm, including attacks of brightness, contrast, histogram equalization, attacks of different noise in addition to the image cutting, filtering and etc.. The results indicate that the novel algorithm based on wavelet coefficient comparison can increase the transparency and the robust of the image, compared with the traditional method.

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