A Novel Multiple Watermark With ROI Recovery

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***Abstract*—A novel multiple watermarking scheme was proposed, which could embed the reversible watermark in ROI (region of interest) by improving the Ni's algorithm, and the robust watermark in non-ROI by quantizing the low frequency coefficients. The watermarks can simultaneously achieve copyright protection and content authentication, and the ROI of the watermarked image can be recovered completely if it isn't attacked. At the same time, the multipurpose watermarks are extracted in a blind manner without requiring the original image. The experimental results illustrate that the pure payload of the proposed reversible watermarking algorithm is higher 10 percent than Ni's scheme, and the robust watermark can endure common image attacks.**

Keywords-multiple watermark; reversible watermark; histogram shifting; quantization

I. INTRODUCTION

Copyright marking has recently become an important technique for multimedia information hiding. Its application is broad, including ownership protection[1-2], content authentication[3], side information conveyance [4]and so on.

There are many watermarking algorithms which focus on multiple robust watermarking for ownership embedding[5-8]. However, only few suggestions focus on embedding actually different watermarks. Lu et al.[3] proposed a multipurpose watermarking scheme, in which robust and fragile watermarks were simultaneously embedded for copyright protection and content authentication by quantizing a host image's wavelet coefficients. But all these algorithms can't avoid the mutual interference between different watermarks.

In this paper, we propose a novel multiple watermarking scheme which embeds the reversible watermark in ROI (region of interest) by improving the Ni's algorithm[9], and the robust watermark in non-ROI by quantizing the low frequency coefficients. The watermarks can simultaneously achieve copyright protection and content authentication, and the ROI of the watermarked image can be recovered completely if it isn't attacked. At the same time, the multipurpose watermarks are extracted in a blind manner without requiring the original image. The experimental results illustrate that the pure payload of the proposed reversible watermarking algorithm is higher 10 percent than Ni's scheme, and the robust watermark can endure common image attacks.

II. PROPOSED MULTIPLE WATERMARKING ALGORITHM

This section will elaborate on the proposed approach in detail. In Section A, a novel reversible watermarking algorithm is proposed to embedded the watermark in the ROI. In Section B we modulate the low frequency coefficients to embed the robust watermark in the remaining image.

The ROI(region of interesting), called I_0, is the important part of an image I (L×L) and its size is M×N. The reversible visible watermark (W1) is embedded in I_0, and the robust watermark (W2)is embedded in the remaining part (I_1).

A. Reversible Watermarking

Ni proposed a simple reversible watermarking algorithm based on histogram shifting. We improve the algorithm, which can embed two data into three pixels using the template.

The embedding procedure includes the following steps:

S1) Generate the image's histogram H(x);

S2) In the histogram H(x) find the maximum point h(a) and the minimum point h(b) .

S3) Without loss of generality , assume a<b. all the pixel gray values (satisfying a<x<b) are added by 1,and leave a+1(M) empty.

S4) Scan the image I, record the pixel a(L) and a+2(R). According to the Template (Table1), every two data are embedded into three pixels.

TABLE I. THE RELATIONSHIP BETWEEN THE TWO MARKS AND THE THREE PIXELS

I \ W, I'	0 0	0 1	1 0	1 1
L L L	L L L	L L M	L M L	M L M
R R R	R R R	R R M	R M L	M R M
L R R	L R R	L R M	M R R	L M M
L L R	L L R	L M R	M L R	M M R
R L L	R L L	R L M	M L L	R M M
R R L	R R L	R M L	M R L	M M L
L R L	/	/	/	M M M

B. Actual Data Embedding Capacity and the PSNR of a Marked Image

In this way the actual data embedding capacity C is calculated as follows:

$$C \approx (H(a+1)+H(a+2)-H(b))\times\frac{2}{3} \quad (1)$$

The lower bound of the PSNR of a watermarked image is larger than 48db..

C. Robust Watermarking

In this section, we will describe how to embed watermark in the remaining part. The detailed steps are described as follows:

1) We split the remaining part of the image into non-overlapped blocks of 8 × 8 and then each block is DCT-transformed. We calculate the value of the ith block:

$$Q_i = |f_i(0,1)|+|f_i(1,1)|+|f_i(1,0)|, \quad (2)$$

where $f_i(0,1)$ 、 $f_i(1,1)$ 、 $f_i(1,0)$ are three coefficients of low DCT Frequency.

2) Any Q_i is qualified to embed W_{2i} via the following equations:

$$Q_{iw} = \begin{cases} (2n+1)\Delta & when\ W_{2i}=1 \\ 2n\Delta & when\ W_{2i}=0 \end{cases}, \quad (3)$$

where Δ is the quantization parameter. After quantization the new coefficient is defined as:

$$\begin{cases} f_{iw}(0,1) = f_i(0,1) + \dfrac{f_i(0,1)(Q_i'-Q_i)}{|f_i(0,1)|+|f_i(1,1)|+|f_i(1,0)|} \\ f_{iw}(1,1) = f_i(1,1) + \dfrac{f_i(1,1)(Q_i'-Q_i)}{|f_i(0,1)|+|f_i(1,1)|+|f_i(1,0)|} \\ f_{iw}(1,0) = f_i(1,0) + \dfrac{f_i(1,0)(Q_i'-Q_i)}{|f_i(0,1)|+|f_i(1,1)|+|f_i(1,0)|} \end{cases} \quad (4)$$

3) The IDCT is implemented to produce the watermarked remaining part of the image I_{1w}.

4) I_{1w} and I_{0w} forms the image I_w.

D. The PSNR of a Dual Marked Image and the Quantization Parameter

$$PSNR = 10\times\log_{10}(\frac{255\times255}{MSE}) \quad (5)$$

$$MSE = \frac{\sum_{i=0}^{511}\sum_{j=0}^{511}(I^w(i,j)-I(i,j))^2}{512*512} \quad (6)$$

$$\sum_{i=0}^{511}\sum_{j=0}^{511}(I^w(i,j)-I(i,j))^2 = 64\times64\times\sum_{i=0}^{7}\sum_{j=0}^{7}(I^w(i,j)-I(i,j))^2 \quad (7)$$

$$\begin{aligned} &\sum_{i=0}^{7}\sum_{j=0}^{7}(I^w(i,j)-I(i,j))^2 \\ &=\sum_{j=0}^{7}\sum_{j=0}^{7}\{a(0)a(1)[f^w(0,1)-f(0,1)]\cos_j \\ &+a(1)a(1)[f^w(1,1)-f(1,1)]\cos_j\cos_i \\ &+a(0)a(1)[f^w(1,0)-f(1,0)]\cos_i\}^2 \end{aligned} \quad (8)$$

Where $a(0)=\sqrt{\frac{1}{8}}, a(1)=\sqrt{\frac{2}{8}}$

$\cos_j = \cos\frac{(2j+1)\pi}{2\times8}, \cos_i = \cos\frac{(2i+1)\pi}{2\times8}$.

$$\begin{aligned} &\sum_{i=0}^{7}\sum_{j=0}^{7}(I^w(i,j)-I(i,j))^2 \\ &=\sum_{j=0}^{7}\sum_{j=0}^{7}\frac{\Delta^2}{36}\{a(0)a(1)\cos_j + a(1)a(1)\cos_j\cos_i \\ &+a(0)a(1)\cos_i\}^2 \\ &\approx 0.10036\Delta^2 \end{aligned} \quad (9)$$

So we can find

$$\begin{aligned} MSE &= \frac{\sum_{i=0}^{511}\sum_{j=0}^{511}(I^w(i,j)-I(i,j))^2}{512*512} \\ &= \frac{(\frac{512\times512}{8\times8}-\frac{144\times120}{8\times8})*0.10036\Delta^2+144\times120}{512*512} \end{aligned} \quad (7)$$

If PSNR>48, Δ <25.66. In our paper we choose 25.

III. THE RECOVERY OF ROI AND THE EXTRACTION OF ROBUST WATERMARK

A. Recovery of ROI and Watermark Extraction

1) Scan the watermarked image I' in the same sequential order as in embedding steps. Record the pixels with its gray value a(L), a+1(M), a+2(R), the watermark is extracted and the gray value can be calculated through the Template.

2) Scan the image again, . all the pixel gray values (satisfying a<x<b+1) are decreased by 1, and the original gray value can be recover.

B. Extraction of Robust Watermark

We split the corrupted watermarked image I_w' into non-overlapped blocks of 8 × 8. Let $f_{iw}'(0,1)$, $f_{iw}'(1,1)$ and $f_{iw}'(0,1)$ denote the DCT coefficients of the ith block as in embedding. Then we compute Q_{iw}' by:

$$Q_{iw}' = | f_{iw}'(0,1) | + | f_{iw}'(1,1) | + | f_{iw}'(1,0) | . \quad (10)$$

The robust watermark W_2' is extracted by:

$$W_{2i}' = \begin{cases} 1 \quad when \left\lfloor \frac{Q_i'}{\Delta} + 0.5 \right\rfloor is\ odd \\ 0 \quad when \left\lfloor \frac{Q_i'}{\Delta} + 0.5 \right\rfloor is\ \ even \end{cases} . \quad (11)$$

To determine if a watermark exists, we compute the normalized correlation NCr between W_2' and W_2 as follows:

$$NC_r = \frac{W_{2i} \bullet W_{2i}'}{(W_{2i} \bullet W_{2i})^{\frac{1}{2}}} \quad (12)$$

IV. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed watermarking algorithm, a gray Lena image (512×512, Figure 1) is the host images, and the face of Lena is the ROI (120×144). The reversible watermark (40×10) and the robust watermark (55 ×55) are shown in Figure 2. Two dual watermarked images are shown in Figure 3. Δ is 25 for robust watermark, which can get the good comprise between invisibility and robustness.

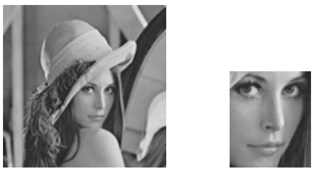


FIGURE I. LENA AND ROI

FIGURE II. REVERSIBLE WATERMARK AND ROBUST WATERMARK

FIGURE III. THE LENA AFTER EMBEDDING MULTIPLE WATERMARKS(PSNR=48.9297)

A. *Reversible Watermark*

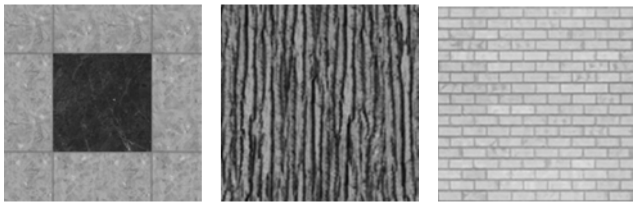
The proposed reversible watermarking algorithm has been applied to many different type of images, including some commonly used images, medical images (Figure 3), texture images(Figure 4) and aerial images(Figure 5). The results are presented in Table2.

(1) (2) (3)

FIGURE IV. MEDICAL IMAGE 1-3

TABLE II. COMPARISON BETWEEN NI'S SCHEME AND OUR PROPOSED METHOD ON IMAGES TABLE TYPE STYLES

Image （**512×512×8**）	**Ni**		**our**	
	payload	***PSNR***	***payload***	***PSNR***
Babala	4563	48.1693	4760	48.3250
Boat	7301	48.3620	10462	48.2973
Airplane	16171	48.2765	17792	48.4141
Lena	5460	48.1764	5512	48.2173
Medical image1	56139	48.6181	74790	48.8520
Medical image2	50560	48.5687	67348	48.7853
Medical image3	50222	48.5658	66866	48.7699
Texture image1	15300	48.2588	15886	48.3858
Texture image2	17750	48.2796	19220	48.4268
Texture image3	22988	48.3238	23548	48.4965
Aerial image 1	10824	48.2221	11292	48.3094
Aerial image 2	6365	48.1838	6562	48.2365
Aerial image 3	10128	48.2236	10400	48.3037



(1) (2) (3)

FIGURE V. TEXTURE IMAGE 1-3

(1) (2) (3)

FIGURE VI. MEDICAL IMAGE 1-3

B. *Robust Watermark*

To check the robustness of the watermark, we perform several attacks on the watermarked image:

1) JPEG;

2) Image processing operation;

3) Geometry attack.

JPEG (JP) with QF (Quality factor) =35%, 40%, 45%, 50% 60%,70%, 80%, 90%, 100%, The image processing operation includes: 3×3 median filtering, 5×5median filtering, 7×7 median filtering, 3×3 Gaussian filtering, 5×5 Gaussian filtering, jitter attack, gray stretching, blurring, sharpening, changing the brightness/contrast, γ -emendation, histogram equalization, uniform noise adding, and salt and pepper noise addition. Geometry attack includes: image scaling (SC) with 50%, 110%, 150%,200%, image rotation 0.25,clipping after rotation, slight affine attack. Three kinds of attacks are selected to test the robustness of our watermarking scheme. Figure 6 explains the robust watermark detection results.

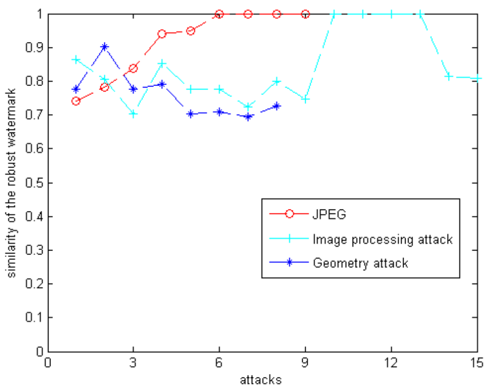


FIGURE VII. THE SIMILARITY OF THE EXTRACTED ROBUST WATERMARK AFTER DIFFERENT ATTACKS

V. CONCLUSION

In this paper, we propose a novel multiple watermarking scheme which embeds the reversible watermark in ROI (region of interest) by improving the Ni's algorithm, and the robust watermark in non-ROI by quantizing the low frequency coefficients. The watermarks can simultaneously achieve copyright protection and content authentication, and the ROI of the watermarked image can be recovered completely if it isn't attacked. The experimental results illustrate that the pure payload of the proposed reversible watermarking algorithm is higher 10 percent than Ni's scheme, and the robust watermark can endure common image attacks.

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