Wavelet-Based Reversible and Visible Image Watermarking Scheme

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Abstract. A visible reversible image watermarking scheme embeds visible watermark into digital images for ownership identification and the embedded watermark can be removed to recover the original image. The proposed scheme first partitions the cover image to four similar images with half size in width and height. These 4 images are classified to two sets, fixed set (*FS*) and watermarked set (*WS*), and each image is then applied to forward wavelet transform for acquiring 4 low-pass subimages for embedding watermark image. The number of *FS* and *WS* determines the stability or visibility of embedded watermarks. The coefficients in *FS* are stationary and the watermark image is embedded into low-pass coefficients of *WS* based on low-pass coefficients of *FS*. Experimental results show that the proposed scheme has good watermark similarity and good extraction result under cropped or noise attacks.

Keywords： visible watermark, reversible watermark, wavelet transform

1 1. Introduction

Nowadays, digital images are popularly used because of the rapid growth in computer network. Therefore, determining the ownership of an image is an important issue. Watermarking techniques have become more and more important in solving this authentication problem for protecting vital images. The techniques embed user information by adjusting an image, and such modification is always irreversible and invisible. Consequently, the original image cannot be noticed and recovered after extracting the embedded watermarks. However, some applications need to obtain the original image for clearly checking image content. Moreover, the embedded watermarks might be observed in some applications for better representing the ownership of digital images. The reversible and visible image watermarking are then acquired.

Research on reversible watermarking approaches include invisible and visible. Invisible reversible watermarking approaches are first solved by adjusting image pixels. Tian [6] embedded each watermark bit into the LSB of two times of the difference

adfa, p. 1, 2011.

between two pixels. Alattar [1] calculated the difference expansion of the integer transformation to embed watermarks. Ni *et al.* [5] embedded watermarks using the histogram of an image. A watermark bit 1 is embedded by adding the peak-pixel value in histogram, while embedding a 0 involves no modification.

Some visible reversible image watermarking schemes are then presented. Hu and Jeon [2] presented a reversible visible watermarking approach that utilizes two data packets payloads to recover watermark-covered and non-watermark covered regions. The payload is hidden in a region that is not covered by a visible watermark, enabling the image to be reversibly recovered. Lin *et al*. [3] presented a structure to embed reversible and visible watermarks into four similar images that are partitioned from the cover image. Liu and Tsai [4] presented a generic one-to-one compounding mapping function to adjust pixel values to visible watermarks. Yang *et al*. [8] embedded the watermarks into user-selected region and inserted the reversible information into non-visibly-watermarked region.

The paper presents a wavelet-based reversible and visible image watermarking scheme. The proposed scheme first partitions the cover image to four similar images with half size in width and height. These four images are applied to forward wavelet transform for acquiring four low-pass subimages and then classified to two sets. The first one is fixed set (*FS*) and another one is the watermarked set (*WS*). The number of *FS* and *WS* determines the stability or visibility of watermarks. In our experiments, the number of *FS* is 1 and the number of *WS* is 3 for the largest embedded quantity. The coefficients in *FS* are stationary and watermarks embedding into *WS* are based on values of *FS*. The proposed scheme has two significant properties. First, the proposed scheme increases the contrast by moving dark pixels to bright ones and bright pixels to dark ones. Therefore, the watermarked image is highly visible. Second, no logo image is required to recover the watermarked to original cover image.

The rest of this paper is organized as follows. Section 2 introduces the proposed wavelet-based reversible and visible image watermarking method. Section 3 presents the experimental results of the proposed method. Comparisons with other related works are also provided. Finally, Section 4 draws a brief conclusion.

2 Proposed Method

This section illustrates the proposed wavelet-based reversible and visible image watermarking method. Users should first define two sets *FS*, *WS*, and one value *rqs* for determining the significance and reversibility of the watermarked image. Since the proposed scheme partitions the cover image into four similar images, at least one image should be fixed as denoted by *FS*, and another image should be embedded watermarks as denoted by *WS*. *FS* denotes the set of fixed images that the images are invariant before and after embedding watermarks, and *WS* denotes the set of images that watermarks are embedded into, and *rqs* represents the relative quantity shift that embeds into the *WS* images. The proposed watermark embedding and extracting algorithms are introduced in Sections 2.1 and 2.2, respectively.

2.1 Watermark Embedding Algorithm

This section presents the embedding algorithm of the proposed reversible and visible image watermarking approach. Given a cover image C of size $2^M \times 2^N$, the proposed method first partitions the image to four similar images $C_p(0 \le p \le 3)$ with size $2^{M/2} \times 2^{N/2}$. For an image $C_p(0 \le p \le 3)$ with size $2^{M/2} \times 2^{N/2}$, applying *1*-level wavelet transform acquires the LL subimage with size $2^{\frac{M}{2^2}} \times 2^{\frac{N}{2^2}}$ and applying t-level wavelet transform acquires the LL subimage with size $2^{\frac{M}{2^{t+1}}} \times 2^{\frac{N}{2^{t+1}}}$. For the simplicity of explanation, t is set to 1 in the following and the size of LL subimage is $2^{M/4} \times 2^{N/4}$, which is assumed the same to the size of the binary watermark image B. Denote that *1*-level wavelet LL subimages of images $C_p(0 \le p \le 3)$ are $L_p(0 \le p \le 3)$, respectively. Each $L_p(0 \le p \le 3)$ is then belonged to FS or WS, and the set of FS and WS are denoted by L_{FS} and L_{WS}, respectively.

Binary watermark image pixels, denoted by $B(i,j)$, are embedded into L_{WS} using user-defined L_{FS} and rqs. For increasing the watermark visibility, number of the set FS is always restricted to 1. Number of L_{WS} can be 1, 2, or 3. Large L_{WS} or larger rqs acquires apparently watermark visibility. The proposed watermark embedding algorithm is described as follows.

1. Partition the cover image C of size $2^M \times 2^N$ into 4 similar images $C_p(0 \le p \le 3)$ of size $2^{M/2} \times 2^{N/2}$ by Eq. (1)

$$\begin{aligned} &C_1(i,j) = C(2i,2j), \qquad C_2(i,j) = C(2i+1,2j) \\ &C_3(i,j) = C(2i,2j+1), \quad C_4(i,j) = C(2i+1,2j+1) \end{aligned} \tag{1}$$

where $0 \le i \le 2^{M/2}-1$, $0 \le j \le 2^{N/2}-1$.

2. Apply $C_p(0 \le p \le 3)$ to *1*-level wavelet transform to acquire *1*-level wavelet LL subimages $L_p(0 \le p \le 3)$.

3. Use the wavelet LL subimage of L_{FS} and user defined relative quantity shift rqs to calculate parameters *center* and *eq* by Eq. (2)

$$\begin{aligned} &diff = l_{\max} - l_{\min} \\ &center = \frac{l_{\max} + l_{\min}}{2} \\ &eq = \frac{diff}{2} - rqs \end{aligned} \tag{2}$$

where $l_{\max}$ and $l_{\min}$ denote maximum and minimum coefficients in L_{FS}, respectively.

4. Embed binary watermark image B into each L_p in L_{WS} using Eq. (3)

$$\begin{aligned} &L'_{WS}(i,j) = L_{WS}(i,j) - B(i,j) \times eq, \qquad if \quad L_{FS}(i,j) > center \\ &L'_{WS}(i,j) = L_{WS}(i,j) + B(i,j) \times eq, \qquad if \quad L_{FS}(i,j) \le center \end{aligned} \tag{3}$$

where (i, j) denote image indexes and with the range of $0 \le i \le 2^{M/4}-1$, $0 \le j \le 2^{N/4}-1$.

5. Apply inverse wavelet transform on L_{FS} and L'_{WS} to acquire partitioned watermarked images C'_p $(0 \le p \le 3)$.

6. Acquire the watermarked image C' from C'_p $(0 \le p \le 3)$ by Eq. (4)

$$C'(2i,2j)=C'_1(i,j),\qquad C'(2i+1,2j)=C'_2(i,j)$$
$$C'(2i,2j+1)=C'_3(i,j),\qquad C'(2i+1,2j+1)=C'_4(i,j) \tag{4}$$

where $0 \le i \le 2^{M/2}-1$, $0 \le j \le 2^{N/2}-1$.

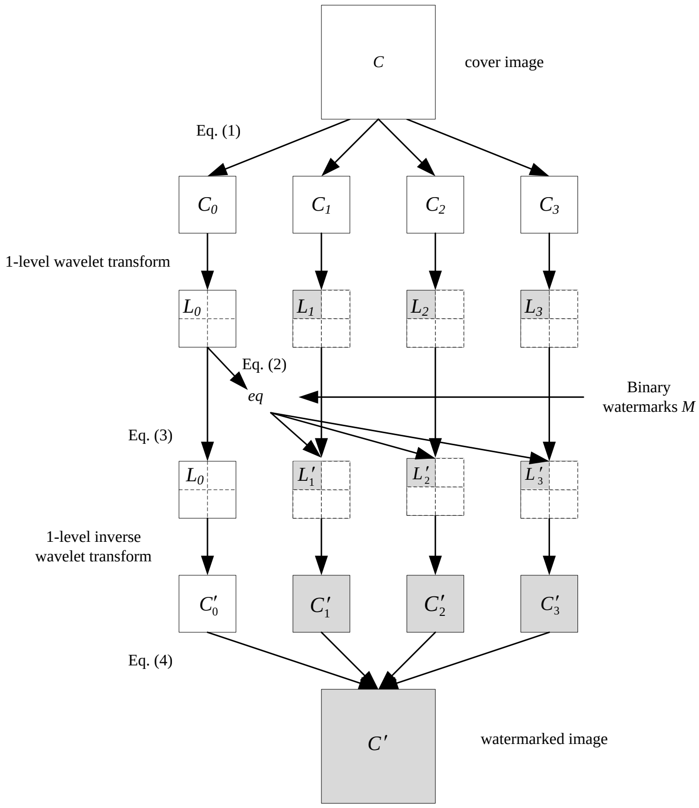


Fig. 1. Example of embedding steps by $FS=\{C_0\}$ and $WS=\{C_1, C_2, C_3\}$.

Fig. 1 depicts the embedding steps of using $FS=\{C_0\}$ and $WS=\{C_1, C_2, C_3\}$ to embed watermarks. In the proposed embedding algorithm, watermarks only embed into *LL* subimage of the set of *WS*, as denoted by $L_p(1 \le p \le 3)$. The images or subimages that modified after embedding watermarks are drawn as gray blocks in Fig. 1. Other wavelet subimages are invariant and those invariant subimages are drawn as white blocks in Figure 1. Since this example embeds watermarks into three wavelet *LL* subimages $L_p(1 \le p \le 3)$, the embedded watermark is highly visible. The watermarks can be only embedded into one wavelet *LL* subimage for lightly visible effect. Moreover, the condition fitting the following criterion in Eq. (5) should be remarked and extra record the information $(p, i, j, L_i(i,j))$.

$$\text{Record}(p,i,j,L_i(i,j)) \quad \text{if } \left(L'_i(i,j) < l_{\min}\right) or \left(L'_i(i,j) > l_{\max}\right) or \left(\left|L_{WS}(i,j) - L_{FS}(i,j)\right| < rqs\right) \tag{5}$$

Therefore, by recording the unrecovered information using extra storage, the embedded watermarks can be perfectly extracted and recovered the original cover image.

2.2 Watermark Extracting Algorithm

This section demonstrates the watermark extracting algorithm, in which the original cover image is obtained after extracting the visible watermark image. Excepting the watermarked image W, two sets FS, WS and one parameter rqs should also be provided. The watermarked image W is partitioned to four similar images $W_p(0\leq p\leq 3)$. Each image W_p is applied the forward wavelet transform and we denote that L'_p $(0\leq p\leq 3)$ be the LL subimage of 1-level wavelet coefficients.

The proposed watermark extracting algorithm is described as follows.

1. Partition the watermarked image W of size $2^M\times 2^N$ into 4 similar images $W_p(0\leq p\leq 3)$ of size $2^{M/2}\times 2^{N/2}$ by Eq. (6)

$$\begin{aligned} &W_1(i,j)=W(2i,2j), \qquad W_2(i,j)=W(2i+1,2j) \\ &W_3(i,j)=W(2i,2j+1), \quad W_4(i,j)=W(2i+1,2j+1) \end{aligned} \tag{6}$$

where $0\leq i\leq 2^{M/2}-1$, $0\leq j\leq 2^{N/2}-1$.

2. Apply $W_p(0\leq p\leq 3)$ to 1-level wavelet transform to acquire 1-level wavelet LL subimages $L_p(0\leq p\leq 3)$.

3. Use the wavelet LL subimage of L_{FS} and user defined relative quantity shift rqs to calculate the embedded quantity eq by Eq. (7)

$$\begin{aligned} &diff = l_{\max} - l_{\min} \\ &center = \frac{l_{\max}+l_{\min}}{2} \\ &eq = \frac{diff}{2} - rqs \end{aligned} \tag{7}$$

where $l_{\max}$ and $l_{\min}$ denote maximum and minimum coefficients in L_{FS}, respectively.

4. Replace the store record in Eq. (5) to wavelet LL subimages.

5. Extract watermark image M_{WS} from L_{WS} and recover to L'_{WS} using Eq. (8)

$$\begin{aligned} &if\ \left(\left|L_{WS}(i,j)-L_{FS}(i,j)\right| < rqs\right) \\ &\quad M_{WS}(i,j)=0, \\ &\quad L'_{WS}(i,j)=L_{WS}(i,j) \\ &elseif\ \left(L_{WS}(i,j)-L_{FS}(i,j)\geq rqs\ and\ \ L_{FS}(i,j) > center\right) \\ &\quad M_{WS}(i,j)=1, \\ &\quad L'_{WS}(i,j)=L_{WS}(i,j)+eq \\ &elseif\ \left(L_{WS}(i,j)-L_{FS}(i,j)\geq rqs\ and\ \ L_{FS}(i,j)\leq center\right) \\ &\quad M_{WS}(i,j)=1, \\ &\quad L'_{WS}(i,j)=L_{WS}(i,j)-eq \end{aligned} \tag{8}$$

where (i, j) denote image indexes and with the range of $0\leq i\leq 2^{M/4}-1$, $0\leq j\leq 2^{N/4}-1$.

6. Apply inverse wavelet transform on L_{FS} and L'_{WS} to acquire partitioned watermarked images C'_p $(0\leq p\leq 3)$.

7. Acquire the recovered cover image C' from C'_p $(0\leq p\leq 3)$ by Eq. (4)

8. Acquire the recovered watermark image M from M_{WS} by Eq. (9)

$$M(i,j) = majority(M_{WS}(i,j)) \tag{9}$$

where *majority* denotes majority number between $M_{WS}(i, j)$, and (i, j) denote image indexes with the range of $0 \le i \le 2^{M/4}-1$, $0 \le j \le 2^{N/4}-1$.

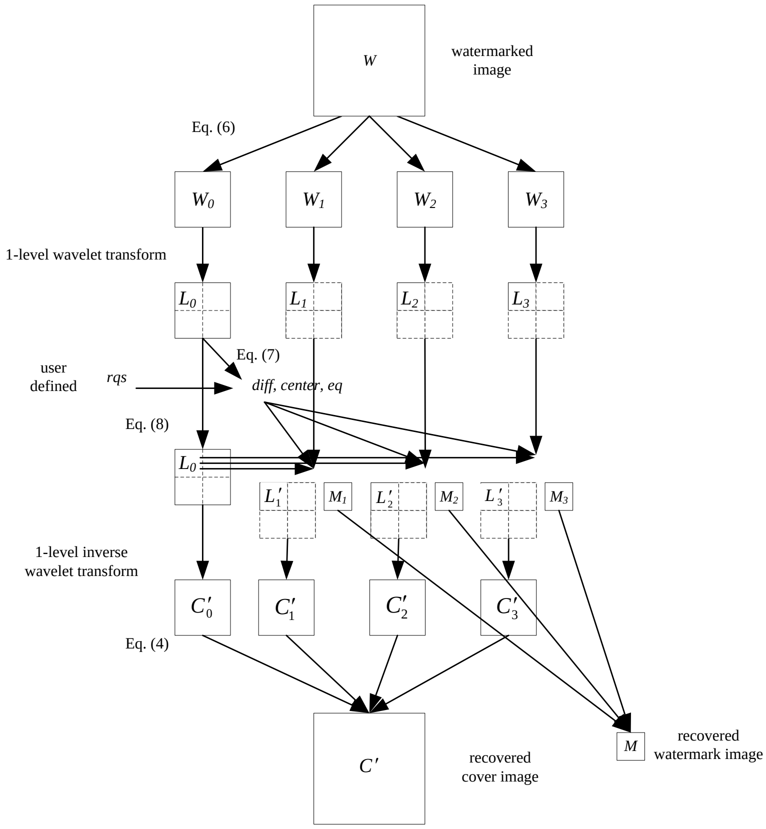


Fig. 2. Example of extracting steps by $FS=\{W_0\}$ and $WS=\{W_1, W_2, W_3\}$.

Fig. 2 depicts the extracting steps of $FS=\{W_0\}$ and $WS=\{W_1, W_2, W_3\}$. In this example, W_0 is only referenced to extract watermark from $W_p(1 \le p \le 3)$. Therefore, W_0 is stationary. However, wavelet *LL* subimages L_p of W_p are checked by Eq. (8) to extract watermark M_p and recover to L'_p. The overflow or underflow information, calculated in Eq.(5), is replaced to L_{FS} wavelet *LL* subimages in Step 4. Then, applied the extracting algorithm will recover to the original cover image and extract the watermark image.

3 Experimental Results

This section presents the experimental results of the proposed scheme. All experiments were performed on MATLAB 7.11 on a Notebook with an Intel i7-2677 CPU and 4GB of RAM. Figs. 3(a)-(c) show three test grey images Cameramen, House, and

Boat of size 512×512 and Fig. 3(d) shows the binary watermark image of size 128×128. Since the extra record calculated in Eq.(5) is adopted to store extra condition for perfect recovery, the following experiments are performed without using the extra record to demonstrate the performance of our original proposed scheme.

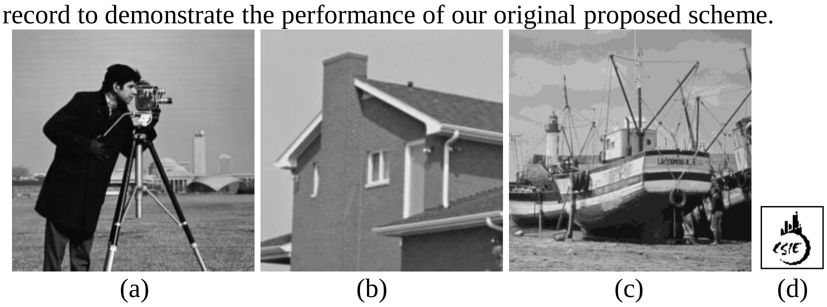


Fig. 3. (a)-(c) three test grey images of size 512×512, (d) the binary watermark image of size 128×128

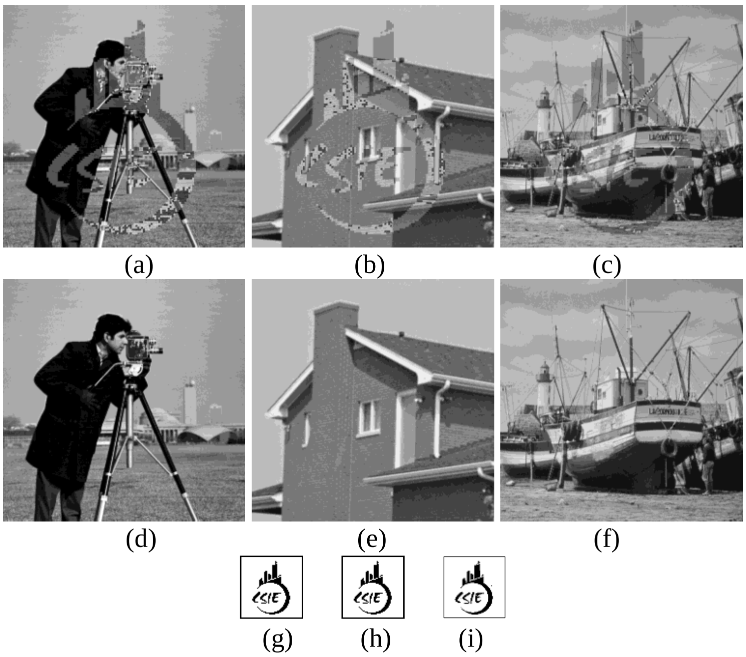


Fig. 4. (a)-(c) three watermarked images, (d)-(f) three recovered cover images, (g)-(i) three recovered watermark images.

Fig. 4 shows the watermarked images and extracted images, including recovered cover images and recovered watermark images, of applying cover images and the watermark image in Fig 3. Fig. 4 adopts the user-defined *rqs* as 40 and the embedded watermarks are clearly recognized in Figs. 4(a)-4(c). Since no extra record is stored in this experiment, the recovered cover image may not always identical to the cover images in Fig 3. The embedded watermarks in Figs. 4(a) and 4(b) are clearly erased from the watermarked images and the recovered cover images in Figs. 4(d) and 4(e) are identical to Figs. 3(a) and 3(b), respectively. However, the recovered cover image in Fig. 4(f) is a little different to the original cover image in Fig. 3(c). Table 1 lists the extracted watermark similarity and PSNR values of the recovered cover image corresponding to the *rqs* value in these three test images. The watermark similarity displays the similarity between the recovered watermark image and original binary watermark image. Higher watermark similarity value leads to better extracted result and watermark similarity has the optimized value of 1. In Table 1, *rqs*=40 leads to perfect recovery in cover images Cameraman and House. But the recovered watermark image of Fig. 4(c) has a difference of 15 pixels to the original watermark image and the watermark similarity is $\frac{16369}{16384}=0.999084$. The corresponding recovered cover image quality is 43.4036 dB. When *rqs*=30, the watermark similarity is lower than the similarity of *rqs*=40 as listed in Table 1.

Table 1. Experimental results in watermark similarity, PSNR of recovered cover image under two different *rqs* values.

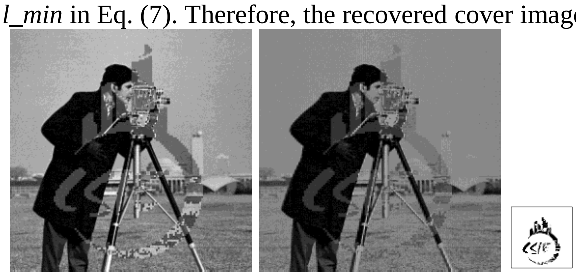
test images	*rqs* value	watermark similarity	PSNR
Cameramen	30	1	∞
Cameramen	40	1	∞
House	30	$\frac{16362}{16384}=0.998657$	39.9671
House	40	0	∞
Boat	30	$\frac{16355}{16384}=0.997009$	37.0547
Boat	40	$\frac{16369}{16384}=0.999084$	43.4036

(a) (b) (c) (d)

Fig. 5. The cropped attack experiment, (a) cropped watermarked image, (b) cropped original cover image, (c) cropped recovered cover image, (d) extracted watermark image.

Fig. 5 shows experimental results of watermarked image suffered from cropped attack. This experiment preserves central area of the watermarked image and then applying the watermark extraction procedure. Fig 5 shows that the cropped recovered cover image in Fig. 5(c) has only several pixels differing with the cropped original cover image in Fig. 5(b) and the PSNR value is 30.1703dB. The extracted watermark, as shown in Fig. 5(d), has the watermark similarity value 1 to show the best extracted result. This property shows that the proposed scheme is good for resisting cropped attack.

Fig. 6 shows experimental results of watermarked images under Gaussian noise attack. Fig. 6(a) shows the watermarked image of adding Gaussian white noise of mean 0 and variance 0.01. The recovered cover image of Fig. 6(a) is shown in Fig. 6(b) and Fig. 6(c) is the recovered watermark image. Fig 6 shows that the extracted watermark has good visual similarity of the watermark similarity value being $\frac{15633}{16384} = 0.954163$ and the quality of the recovered cover image being 16.8887dB. The recovered cover image still has the watermark effect because of the adding noise altering the coefficients *l_max* and *l_min* in Eq. (7). Therefore, the recovered cover image is not perfect.



(a) (b) (c)

Fig. 6. The Gaussian noise attack experiment, (a) noised watermarked image, (b) recovered cover image, (c) recovered watermark image.

4 Conclusion

This paper presents a wavelet-based reversible and visible image watermarking scheme. The scheme partitions a cover image into 4 similar images, in which one is unchanged for referencing and other three are adopted for embedding watermarks. All four images are then applied to wavelet transform to acquire 4 more similar LL subimages and watermarks are then embedded into three of them. Since one is unchanged, the watermarks can be reversibly extracted and the embedded quantity can be large enough to be visible. Experimental results show that the proposed scheme can embed and extract watermarks and the embedded watermark is apparently with high contrast. The embedded watermark can be extracted under the cropped and the salt & pepper noise attacks. Measuring the largest embedded quantity merits our future study.

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