A Reversible Image Watermarking Scheme with High Contrast Visible Watermarks

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Abstract

A reversible image watermarking scheme recovers the original host image when extracting the embedded watermarks. General reversible image watermarking scheme embeds invisible watermarks. This paper presents a reversible image watermarking scheme with embedding highly contrast visible watermarks. The host image first segments to non-overlapped blocks. Each block then uses two watermarking schemes including difference-expansion based invisible watermarking and high-contrast visible watermarking to embed one watermark bit into the host image. The difference-expansion based invisible watermarking scheme is adopted for extracting the watermark bit. Some extra information is therefore needed to be recorded. The high contrast visible watermarking scheme embeds significant visible watermarks. Experimental results show that the proposed scheme embeds high contrast visible watermarks and the watermarks can be extracted perfectly.

Keywords:
Reversible watermarking, visible watermark, high contrast watermark, difference expansion

1. Introduction

Digital images are popularly used for the rapid growth in computer network. The ownership of an image is therefore an important issue. Watermarking techniques become more and more important in protecting vital images. The techniques adjust a host image by embedding user information as watermarks. The watermarks can be classified to reversible or irreversible which means that the host image can be perfectly recovered or not. The watermarks can also be classified to visible or invisible meaning that the embedded watermarks can be noticed or not. In real applications, visible watermarks are popular for their apparent watermarks. Moreover, the reversible property is also important when we need to recover the original host image. A watermarking scheme both containing visible and reversible properties are thus required.

Research on reversible watermark approaches are mostly focused in invisible embedding strategy. Ni et al. embedded watermarks by shifting peak-pixel value in histogram [16]. Tian embedded one bit into two pixels by enlarging the pixels difference and inserting the bit to the LSB [18]. Alattar calculated the difference expansion of the integer transformation to embed watermarks [3]. Further studies on difference expansion include 2-D difference expansion [2], prediction based difference expansion [4, 10], two embedding directions [6], location map improvements [7, 9, 12], and partial difference expansion [17]. Other applications like applying to medical images [1], combining with genetic algorithm [8], combining with coding technique [14], combining with interpolation and histogram shifting [15], and edge detection [20] are also studied.

Some visible reversible image watermarking schemes are also presented. Hu and Jeon [5] selected two dependent data sets from the host image for embedding watermark and non-watermark information. Lin et al. [11] embedded reversible and visible watermarks into four similar images that are partitioned from the host image. Liu and Tsai [13] used a one-to-one compounding mapping function to adjust pixel values for embedding visible watermarks. Watermarks are needed to recover the original host image. Yang et al. [21] embedded the watermarks into user selected region and embedded the reversible information into invisibly watermarked region.

This paper presents a difference-expansion based visible image watermarking scheme with reversibly recovering the original host image. The host image is segmented to non-overlapped blocks. The block size can be 2×2, 3×3 or more. One watermark bit is embedded in each block with visible and invisible watermarking scheme. Two kinds of watermarking schemes are adopted in each block. One pixel in each block is selected to embed using reversible watermarking scheme and others embed using visible watermarking scheme. Since the difference-expansion method is adopted to embed reversible watermark, some information may require to be recorded for its extending the image pixel value after applying the difference-expansion method. Therefore, some information should be recorded if necessary.

The rest of this paper is organized as follows. Section 2 introduces the proposed difference-expansion 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 scheme

This section introduces the presented difference-expansion based visible image watermarking scheme. Section 2.1 introduces the watermark embedding algorithm. Section 2.2 introduces the watermark extracting and host image recovery algorithm.

2.1 Watermark Embedding Algorithm

This section introduces the embedding algorithm of the proposed scheme. The proposed scheme partitions the host image into non-overlapped $k\times k$ blocks. Parameter k can be the size within the constraint of $2\le k\le N/M$, where sizes of the host image and the watermark image are assumed to be $N\times N$ and $M\times M$, respectively. In each block, these $k\times k$ pixels are partitioned to two sets S_1, S_2 and a pixel y. The set S_1 has $\left\lfloor \frac{k^2}{2} \right\rfloor$ pixels and S_2 has $\left\lfloor \frac{k^2}{2} \right\rfloor - 1$ pixels. Two different watermarking strategies are presented to embed one watermark bit w into a block. Visible watermark is embedded into all block pixels excepting y and reversible watermark is embedded into y. The embedding algorithm is introduced as follows.

1. Partition the host image to non-overlapped $k\times k$ blocks, where $2\le k\le \frac{N}{2M}$.
2. Embed one watermark bit w into a $k\times k$ block B by the following steps.

2.1 Partition pixels in the block to two groups S_1, S_2, and one pixel y, where S_1 has $\left\lfloor \frac{k^2}{2} \right\rfloor$ pixels and S_2 has $\left\lfloor \frac{k^2}{2} \right\rfloor - 1$ pixels.

2.2 Use pre-defined parameter *shift* to embed visible watermark bit w into the block to acquire shifted pixels by Eq. (1) on all pixels excepting y

$$x' = x + w \cdot shift \pmod{256} \tag{1}$$

2.3 Calculate block difference d between S_1 and S_2 with y by Eq. (2)

$$d = \sum_{x_i \in S_1} x_i - \sum_{x_j \in S_2} x_j - y \tag{2}$$

2.4 Use the difference-expansion method to embed the reversible watermark bit w into the block difference d by Eq. (3)

$$y' = 2 * d + w + \left\lfloor \frac{\sum_{x_i \in B} x_i - y}{k^2 - 1} \right\rfloor \tag{3}$$

Since the proposed scheme partitions a block pixels into one pixel y and other pixels in which include two sets S_1, S_2. Assume that sizes of host image and watermark image be 512×512 and 128×128, respectively. Thus, k can be 2, 3, or 4. The parameter k determines the scale of the visible watermark. Larger k value acquires larger watermarked region. Table 1 shows partition examples of k = 2 and 3. Since number of S_2 is one less than number of S_1. Therefore, the block difference d, acquired from Eq. (2), can be taken as difference of the block because the positive number equals to the negative number. Consequently, in most of image blocks, the block difference can be very small and the calculated difference *y'* in Step 2.4 can therefore be small, too.

Table 1. Examples of partition strategies of k = 2 and 3.

k	block definition	y	S_1	S_2
2	$b_{1,1}$ $b_{1,2}$ $b_{2,1}$ $b_{2,2}$	$b_{2,2}$	$b_{1,2}$, $b_{2,1}$	$b_{1,1}$
3	$b_{1,1}$ $b_{1,2}$ $b_{1,3}$ $b_{2,1}$ $b_{2,2}$ $b_{2,3}$ $b_{3,1}$ $b_{3,2}$ $b_{3,3}$	$b_{2,2}$	$b_{1,2}$, $b_{2,1}$, $b_{3,2}$, $b_{2,3}$	$b_{1,1}$, $b_{1,3}$, $b_{3,1}$

2.2 Watermark Extracting and Host Image Recovery Algorithm

This section introduces the algorithm of extracting watermark and recovering the original host image. The recovery algorithm performs nearly the reverse procedure of the embedding algorithm. Like the structure in embedding algorithm, the partitioned block size $k\times k$ and block partition strategy that segments a block into two sets S_1, S_2 and one pixel y should be obtained. The recovery algorithm is introduced as follows.

1. Partition the test image to non-overlapped $k\times k$ blocks, where k is the block size used in embedding algorithm.
2. Use partition strategy in embedding algorithm to extract one watermark bit w from a $k\times k$ block B by the following steps.

2.1 Calculate the block extended difference $\bar{d}$ between S_1 and S_2 with y using Eq. (4)

$$\bar{d} = y - \left\lfloor \frac{\sum_{x_i \in B} x_i - y}{k^2 - 1} \right\rfloor \tag{4}$$

in which sets S_1, S_2, and pixel y are defined the same to that used in embedding algorithm.

2.2 Extract the watermark bit w using Eq. (5)

$$w = \bar{d} \% 2 \tag{5}$$

3. Recover the original block by the following steps.

3.1 Recover the original difference *d'* using Eq. (6)

$$d' = \left\lfloor \frac{\bar{d}}{2} \right\rfloor \tag{6}$$

3.2 Recover the shifted pixel *y'* using Eq. (7)

$$y' = \sum_{x_i \in S_1} x_i - \sum_{x_j \in S_2} x_j - d' \tag{7}$$

3.3 Replace the pixel *y* in block *B* by *y'* calculated after Eq. (7).

3.4 Recover all pixels *x* in block by the new calculated block pixels *x'* and extracted watermark bit *w* using Eq. (8)

$$x = x' - w \cdot shift \pmod{256} \tag{8}$$

Two main steps used in the extracting algorithm. Step 2 extracts the watermark bit embedded in each block. Step 3 recovers the block to original block. The proposed scheme adopts difference-expansion method to embed and reversibly to extract the watermark bit in each block. Moreover, other reversible watermarking methods like histogram shifting can also be adopted to replace the reversible method. Therefore, a good reversible watermarking method leads to a perfect extraction of embedded watermark bit.

3. Experimental Results

This section presents the experimental results, which were performed on MATLAB 7.11 on a Notebook with an Intel i7-2677 CPU and 4GB of RAM, of the proposed scheme. Figures 1(a)-(c) show three host grey images Cameramen, House, and Boat of size 512×512 and Figure 1(d) shows the binary watermark image of size 128×128. Since the sizes of host image and watermark image are 512×512 and 128×128, respectively, the partitioned block size *k*×*k* in embedding and recovering algorithm can be 2×2, 3×3, or 4×4.

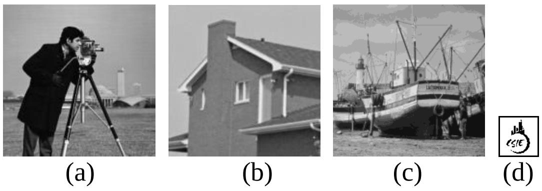
(a) (b) (c) (d)

Figure 1 - (a)-(c) three test grey images of size 512×512, (d) the binary watermark image of size 128×128.

Figures 2 and 3 show the watermarked images under various *k* and *shift*. Parameter *k* determines the areas of watermarked region and parameter *shift* determines the significance of the watermark. First, figure 2 shows experimental results of *shift*=128 and *k*=2 and 3. In watermark region, *k*=2 leads to the watermarked region being 256×256 when the size of logo image is 128×128. Larger *k* assignment has wider watermarked region. *k*=3 or 4 modify a region of 384×384 or 512×512, respectively. Figure 2(a)-(c) and 2(d)-(f) show the watermarked region of 256×256 and 378×378 under parameters *k*=2 and 3, respectively. Second, the assignment in Figure 2 of *shift*=128 leads to the largest differences between pixels in watermarked region and pixels in original area. Therefore, some pixels are modified from white to black or from black to white and the watermark looks like noised regions.

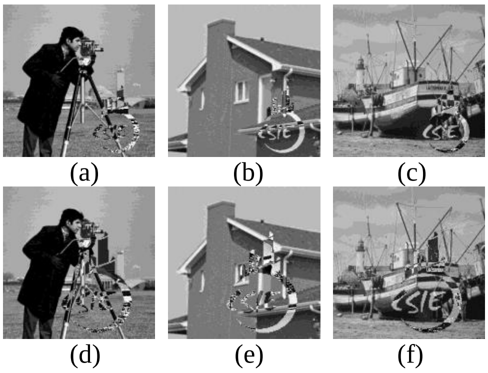
(a) (b) (c)
(d) (e) (f)

Figure 2 - Experimental results of *shift*=128, (a)-(c) three watermarked image under parameter *k*=2, (d)-(f) three watermarked image under parameter *k*=3.

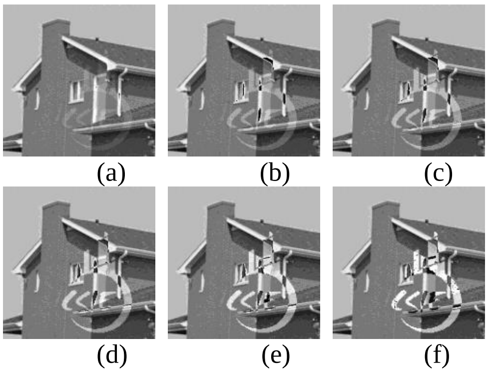
(a) (b) (c)
(d) (e) (f)

Figure 3 - Experimental results of *k* = 3 and (a)-(c) *shift* = 20, 40, 60, (d)-(f) *shift* = 80, 100, 120.

Figure 3 shows experimental results of other *shift* values on test image House. Figures 3(a)-(f) show results of applying *shift*=20, 40, 60, 80, 100, 120 under *k*=3, respectively. These experimental results show that larger *shift* assignment leads to significant watermark effect according with more noises appearing. Moreover, the setting of *shift*=128 gains the most significant watermark effect with largest noises appearing probability. Therefore, the determination of parameter *shift* is a trade-off between watermark effect and noising appearing probability.

4. Conclusion

This paper presents a visible and reversible image watermarking scheme, which is based on the difference-expansion based reversible watermarking scheme. The host image is segmented to non-overlapped blocks for embedding one bit into each block. All block pixels are shifted according to the watermarking bit and the clustering strategy partitions each block into three sets for calculating the block mean difference for reversibly embedding a watermark bit. Usage of the block mean difference reduces the overflow and underflow quantity for reversible watermarking embedding scheme. Merging with other reversible watermarking scheme merits our future study.

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