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Lossless visible watermarking based on adaptive circular shift operation for BTC-compressed images

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Abstract Most existing BTC (Block Truncation Coding) based watermarking algorithms do not fully exploit visual perception of the host images. These schemes cannot obtain visual quality of stego-images and recover original images without distortion. To solve this issue, a new reversible visible watermarking scheme based on AMBTC (Absolute Moment Block Truncation Coding) domain is proposed. First, the proposed scheme uses adaptive pixel circular shift operation that adapts to local properties of the image to embed the visible watermark into two level (one-bit) nonparametric quantization levels of AMBTC according to the parity of the bit plane of AMBTC triple. The watermark signal can be extracted according to the parity of the Bit plane. The experimental results prove that the algorithm can achieve high visual quality of stego-images and recover original BTC-compressed image losslessly. Moreover, it is robust against common signal processing attacks. The visible watermarking algorithm can be applied to copyright of digital images in real-time environment because of the low time consumption due to the simplicity of AMBTC.

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1 Introduction

Usually, an effective data hiding scheme provides three major properties [7]: (i) Imperceptibility (ii) Robustness and (iii) Unambiguity. The secret data to be hidden must be imperceptibility and invisible because of two primary concerns. Firstly the quality of the original image should not be degraded or it will break the aesthetic feeling and diminish the commercial value of the original image. Second, the hidden data should be hard to be detected by hackers, or it will be easily broken or be removed. Information hiding techniques today include digital watermarking and steganography [8]. Digital watermarking describes those methods which embed secret message transparently into a carrier cover. The main concern of digital watermarking is to protect the ownership of a digital content without perceivable degradation. High capacity watermarking includes two categories; irreversible watermarking and reversible watermarking. Presently many irreversible and reversible watermarking techniques have been developed for digital images, and most of them are irreversible [9]. Irreversible watermarking schemes mean that the original image quality is not satisfied after the extraction of the secret data. In other hand, reversible schemes [14] completely recover both original image and hidden data after extraction. Many special application need to recover the original image without no distortion after data extraction, such as military, forensic and medical.

Generally the existing schemes of reversible watermarking algorithms consist of two categories: spatial domain and transform domain algorithm. Spatial domain reversible watermarking [13] directly modifies the image pixel values in the spatial domain to achieve reversibility. Since this technique is easy to implement, offer a relatively high hiding capacity, and the quality of the cover image can be easily controlled, it has become a popular method for reversible watermarking technique. As for reversible watermarking in compressed domain [2], reversibility for this type of watermarking scheme is achieved by modifying the transform domain coefficients. Since most images are transmitted over the internet in compressed format, inserting secret data into the compress domain would arouse little suspicion [3]. However, compressed domain reversible watermarked often suffers from high computational cost and low stego-image quality.

A few works has been done in reversible watermarking, most of them focus on spatial domain [1, 3]. Since most digital images are stored in compressed forms, such as JPEG, JPEG2000, Vector Quantization (VQ) and Block Truncation Coding (BTC). So it is important to develop more reversible watermark algorithms in compressed domain. In 2006, Chang and Lin [2] proposed a reversible data embedding mechanism for VQ compressed images. They used side matching and relocation techniques to achieve reversibility without using the location map. However, the computational cost for their method is high, and is not suitable for real-time applications. In 2007, Chang et al. [5] proposed a new reversible data hiding technique in the VQ-compressed domain further, and the newly proposed method has the benefit of high efficiency of the embedding and extraction process. However, the quality of the stego-image depends largely on a specially designed code map and distortions of the stego-image may become unacceptable if a poor code map is selected.

Many watermarking algorithms based on BTC are proposed in the literature due to the simplicity of BTC methods in recent years. Guo et al. [6] proposed a watermarking algorithm combining order dither block truncation coding, which has low computing cost and good robustness. Chang et al. [4] proposed a reversible watermarking scheme for BTC compressed images. This method can embed one more bit in each BTC-encoded block. Shi and Li [12] proposed a dual image watermarking algorithm based on block truncation code and quad tree segmentation, and it has good robustness against the common image processing attacks. However, the above-mentioned BTC based watermarking algorithms belong to invisible watermarking schemes. In 2014, we proposed a visible watermarking algorithm for BTC compressed image by considering visual masking characteristics [10]. But this scheme cannot recover the original image from the watermarked image. And then we proposed a removable visible watermarking algorithm based on BTC and chaotic map [15], and it can recover the original image near losslessly. In order to achieve the lossless original image recovery, this paper proposes a new reversible watermarking scheme for BTC–compressed images by exploiting the simplicity of AMBTC, which embeds secret data into AMBTC compressed image bit planes.

2 The basic process of BTC

The another form of BTC is Absolute Moment Block Truncation Coding (AMBTC) [8] which is a block based loss image compression technique for gray-level images and first proposed in 1979 [5]. First, an image with size $M \times N$ is segmented into non overlapping blocks with size of $l \times l$, and a two-level (one-bit) quantizer is independently designed for each block. AMBTC is used to real time application because it is a simple and efficient image compression algorithm. Then the average value ($\overline{x}$) and the standard deviation (δ) are calculated for each block and two expressions are calculated to indicate the moment before and after quantization. So, the original image's block is encoded into a bit plane and two quantization levels (as shown in Fig. 1). The pixels which value are lees than the mean value is set as "0" and the

(a) Original Image

146	142	142
141	141	142
145	145	144

(b) Image sub-block

1	0	0
0	0	0
1	1	1

(c) Bit plane

145	142	142
142	142	142
145	145	145

(d) reconstructed sub-block

Fig. 1 An Example of AMBTC Process ($\overline{x} = 143$, $q = 4$, $x^{+} = 145$, $x^{-} = 142$)

pixels which value are greater than or equal to the mean value are set as "1". It can be described as follows.

$$b_i = \begin{cases} 0 & if \ \ x_i < \overline{x} \\ 1 & else \end{cases} \tag{1}$$

Where x_i is the gray value of the Pixel i. ($i = 1, 2\ldots\ l \times l$), and b_i is the i^th^ element of the bit plane B, $B = \{b_i | b_i = 0 \text{ or } 1, i = 1, 2, \cdots, l \times l\}$.

In AMBTC process, first we can calculate the average value $\overline{x}$ and the standard deviation σ of image sub-blocks with size $l \times l$.

Then two-level quantization is performed for the pixels of the block so that a 0-bit is stored for the pixels with values smaller than the mean, and the rest of the pixels are represented by a 1-bit. The image is reconstructed at the decoding phase from the moments $\overline{x}$ and σ, and from the bit plane by assigning the value x^+ to the 1-value pixels and x^- to the 0-value pixels:[11]

$$x^+ = \overline{x} + \sigma\sqrt{\frac{l \times l - q}{q}} \tag{2}$$

And

$$x^- = \overline{x} - \sigma\sqrt{\frac{q}{l \times l - q}} \tag{3}$$

where q is the number of 1-bits in the image sub-block.

Now, the image sub-block can be encoded with the triple (x^+, x^-, B).

During decoding process, for "0" we use the low quantization level x^- and for "1" we use the high quantization level x^+. That is to say,

$$\hat{x}_i = \begin{cases} x^- & b_i = 0 \\ x^+ & b_i = 1 \end{cases} \tag{4}$$

3 BTC based lossless visible watermarking algorithm

AMBTC is a lossy coding method that achieves low bit rates with good results for digital images. In AMBTC method, each block is compressed by using two quantization levels and one bit plane. Because of its low complexity, low computational cost, and feasibility of implementation. Presently AMBTC is a wide choice for image compression. In this work, we choose two quantization levels and the bit plane to hide secret data and gain reversibility. Detailed visible watermark embedding procedure is shown in Fig. 2. To achieve the high quality of stego-image and lossless recovery of original BTC-compressed images, we exploit the HVS model during watermark insertion. The results showed the visual quality is better than that of the previous work and the original image can be reconstructed exactly.

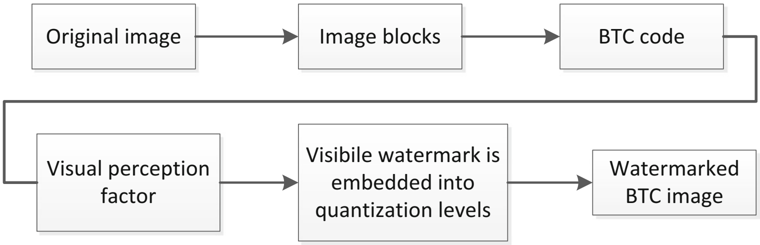


Fig. 2 Flowchart of watermark embedding process

3.1 Lossless watermark embedding

Step 1 Let I be an image ($M \times N$) with 256 gray levels and divide it in to non-overlapping blocks with size $l \times l$, where size l is supposed to be even to ensure the symmetry of the number of 1's and 0's in the bit plane. For each block, we transmit the BTC triple (x^+, x^-, B) firstly.

Step 2 Read a binary image W with size $m \times n$.

$$W = \{w(k)|w(k)\in\{0,1\}, k = 1, 2, \cdots m \times n\} \tag{5}$$

Step 3 Calculating the visual perception factor in AMBTC compressed domain.

For each block, given the BTC triple (x^+, x^- and Bit plane). The smoothness factor of each block can be estimated as,

$$\tau_k = \frac{|l \times l - 2q_k|}{l \times l} \tag{6}$$

Where q_k is the number of 1-bits in the k[th] image sub-block, $k = 1, 2, \cdots m \times n$. The smoothness factor τ_k will be unchangeable before and after watermark insertion because that watermark embedding does not change the absolute difference of the number of 1-bits and 0-bits in bit plane B.

We can obtain the bit depth λ_k of each image sub-block that can be used for watermark insertion by the following formula

$$\lambda_k = round\left\{ (r-1) \times \frac{{}^1/_{\tau_k} - min\left({}^1/_{\tau_k}\right)}{max\left({}^1/_{\tau_k}\right) - min\left({}^1/_{\tau_k}\right)} + 1 \right\} \tag{7}$$

Where *r is an integer*, *and* $1 \le r \le 4$. Function round(x), max(x) and min(x) return nearest integer, the maximum and minimum of the array x respectively.

From Eq. (7), we can see that the less smooth the image sub-block, the greater the bit depth λ_k.

Step 4 Choose a watermark bit from the watermark image W and modify two quantization levels to embed the watermark bit. The corresponding watermark bit is embedded by modified quantization levels of BTC compressed code according to the parity of the Bit plane, and it can be written as follows.

$$\hat{x} = \begin{cases} L(x, \lambda_k) \; and \; Q(B, 1) & if \; w(k) = 1 \; and \; E(B) = 0 \\ L \quad (x, \lambda_k) & if \; w(k) = 1 \; and \; E(B) = 1 \\ x \;\; and \;\; Q \;\; (B, 0) & if \; w(k) = 0 \; and \; E(B) = 1 \\ x & if \; w(k) = 0 \; and \; E(B) = 0 \end{cases} \tag{8}$$

Where $x \in \{x^+, x^-\}$, $L(x, \lambda_k)$ denotes circular left shift operation with λ_k bits on x bit-wisely. Function Q(B, 1) let the number of 1's in Bit plane be even by logical Not operation (note that two quantization levels x^+ and x^- will be exchanged when logical Not operation is applied), while function Q(B, 0) let the number of 1's in Bit plane be odd by logical Not operation instead. Function $E(Z)$ has value 1 when the number of 1's in set Z is even, otherwise 0.

Step 5 Repeat step 3 and step 4 until all the watermark bits are embedded and finally the watermarked stego image I' is generated.

3.2 Watermark extraction and original image recovery

The data hiding scheme is reversible so that the original image requires lossless recovery after watermark extraction. The extraction procedures are as similar as embedding procedures. Given the watermarked image, the watermark extraction process is as follows.

Step 1 Absolute difference of the number of 1-bits and 0-bits in bit plane remains unchangeable both before and after secret message insertion. Therefore, we can calculate the visual perception factor λ_k with Eq. (7).

Step 2 For each AMBTC compressed block, the watermark bit can be extracted according to the parity of the number of 1's in the Bit plane B' of the watermarked image,

$$\hat{w}(k) = \begin{cases} 1 & if \;\; E\left(B'\right) = 1 \\ 0 & else \end{cases} \tag{10}$$

Step 3 Remove the visible watermark from the watermarked image. The original image recovery strategy is as follows.

$$x = \begin{cases} R\left(\hat{x}, \lambda_k\right) & if \;\; \hat{w}(k) = 1 \\ \hat{x} & else \end{cases} \tag{11}$$

Where $R(\hat{x}, \lambda_k)$ denotes circular right shift operation with λ_k bits on $\hat{x}$ bitwise.

In order to give a clear outline of the proposed BCT based visible watermarking scheme, take an image sub-block with size 4×4 ($l = 4$) as an example, the complete procedure of visible watermark embedding and image recovery is illustrated in Fig. 3.

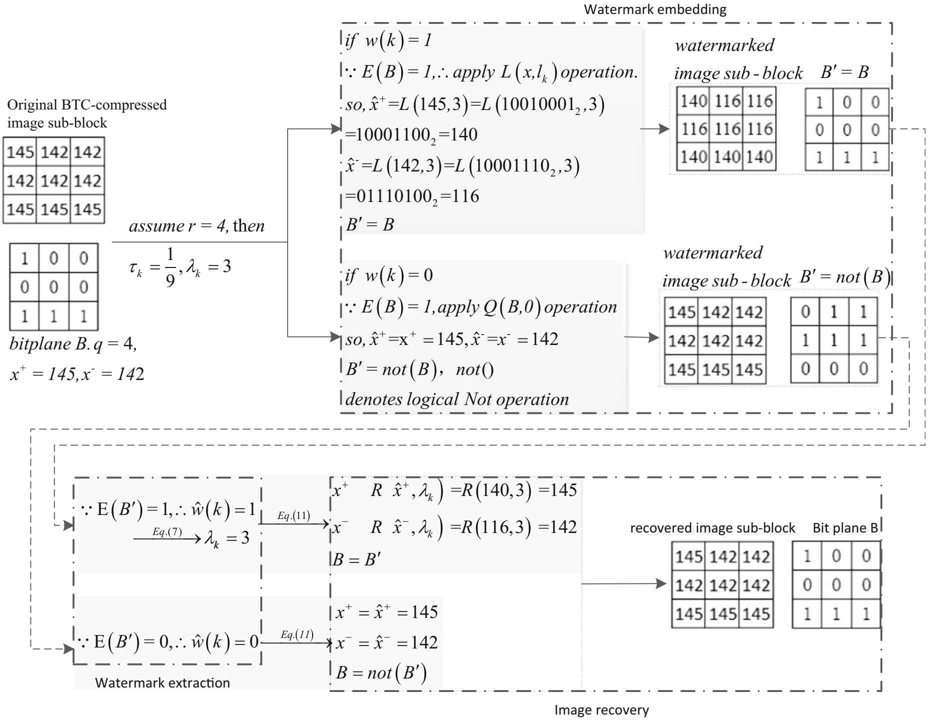


Fig. 3 A complete example of the proposed lossless visible watermarking scheme

Fig. 4 Test images

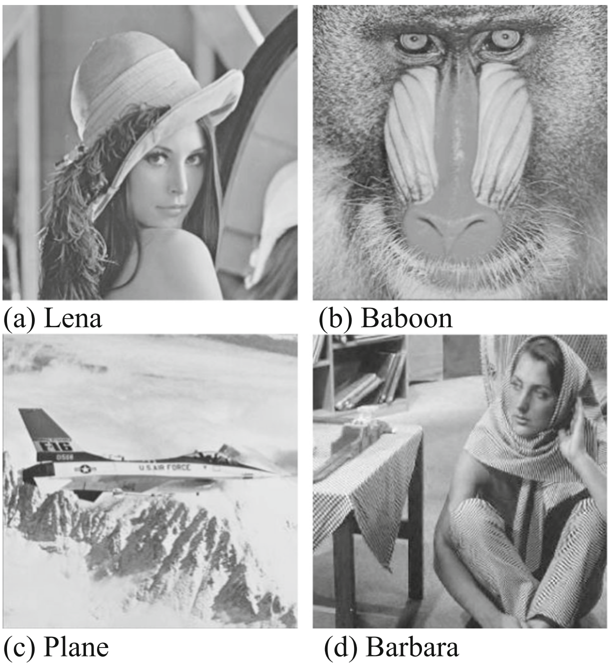


Table 1 Comparison of the stego-image quality under different schemes (dB)

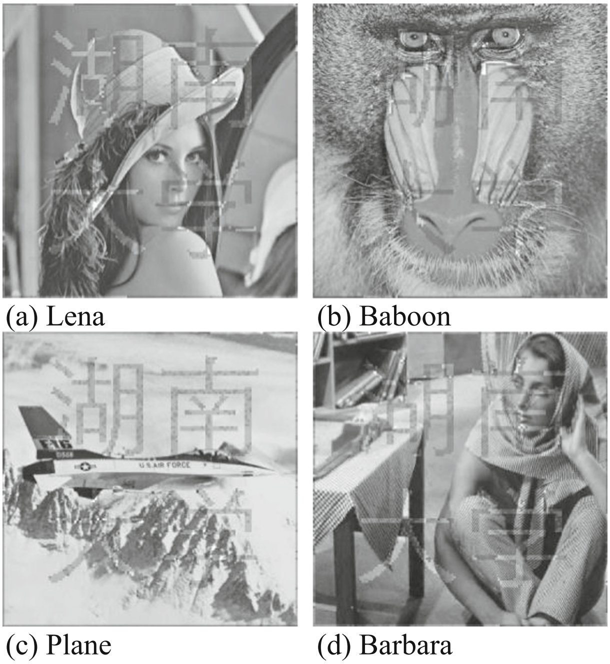
Image	Yang et al. method [15]	Our scheme
Lena	24.0509	24.9162
Baboon	24.1264	24.5284
Plane	23.5584	25.0870
Barbara	23.6865	24.2281
Average	23.8556	24.6899

4 Experimental results

We have tested the performance of the proposed lossless visible watermarking scheme on some typical test image. Four 8-bit gray level images with size 512×512 such as "Lena, Baboon, Plane and Barbara" are shown in Fig. 4. In order to obtain reasonable visual quality of BTC-compressed images, the block size for AMBTC is set to 3×3. Let $r = 4$ in Eq. (7). To assess the AMBTC based reversible visible watermarking scheme, the peak signal to noise ratio (PSNR) is used to measure the distortion between the original image and the stego-image. The computation of PSNR is defined as

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \tag{12}$$

Fig. 5 Watermarked images



$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(x_{ij} x_{ij}^{'} - \right)^{2} \tag{13}$$

Where x_{ij} denote the original pixel value and $x_{ij}^{'}$ denotes the modified pixel value. To investigate the performance of the proposed visible watermarking scheme, we compare the stego-image quality, recovered image quality and hiding capacity of the proposed scheme with Yang et al's method [15] and with scheme. The results are shown in Table 1.

Figure 5 shows the visual quality of stego images generated by the proposed scheme. The visual quality of the watermarked images is good and its average is above 24.60 dB. Detail PSNR value comparison with previous visible watermark algorithm is listed in Table 1. From the data in Table 1, we can see that the visual quality of our scheme is better than previous method, and it has 0.8 dB higher average PSNR value.

From Table 1, we can find that the stego–image of the proposed scheme introduces less distortion after watermark insertion compared to Yang et al.'s method [15]. On the other hand, the proposed method neither requires the design of codebooks, nor the watermark signal for

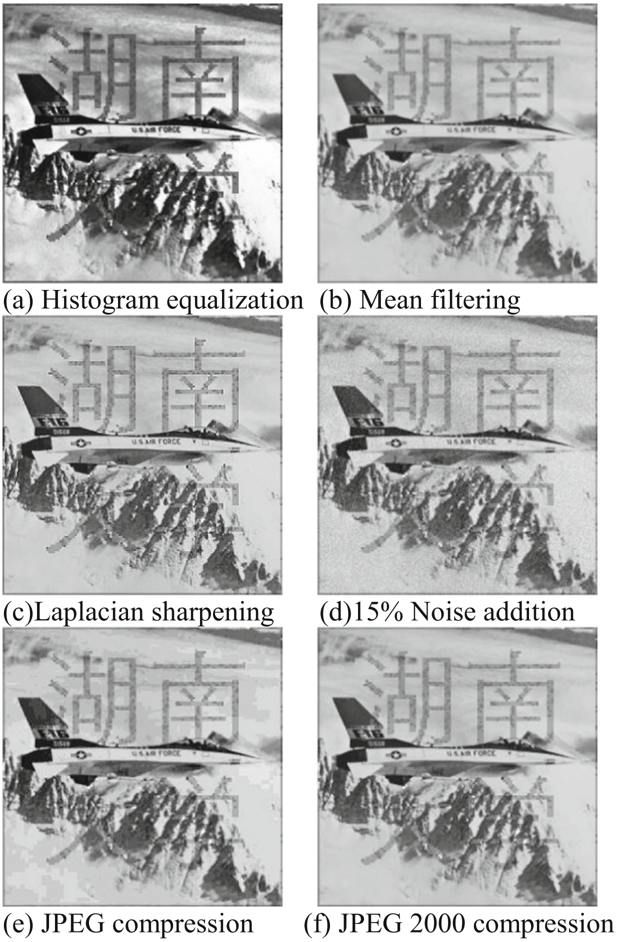


Fig. 6 Robustness against common attacks. (**a**) Histogram equalization (**b**) 3 × 3 Mean filtering (**c**) Laplacian sharpening (**d**) 15 % Noise addition (**e**) JPEG compression with 10 % quality factor (**f**) JPEG 2000 compression with 10 % quality factor

the original image restoration. In addition, Yang et al's method cannot obtain lossless original BTC-compressed image while the proposed scheme can recover original BTC-c0mpressed image losslessly.

In order to test the robustness of the visible watermark, some robustness experimental results are given in Fig. 6 by taking Plane image as an example. Visible watermarks generated by the proposed scheme after being attacked are clearly recognizable. This proves that the visible watermark signal is still in watermarked images. So we can conclude that the proposed visible watermarking algorithm is robust against common signal processing attacks.

5 Conclusions

In this paper, we proposed a new reversible visible watermarking technique, which can be applied to copyright protection for digital images in real-time environment. To reduce the number of bits needed for watermarking a host image, the images are compressed using AMBTC. In our scheme, the watermarked image has good visual quality because of the use of visual perception and extraction procedure is very easy. Moreover, the original BTC-compressed image can be recovered without distortion after watermark removal. The new lossless visible watermarking scheme is robust against to common signal processing attacks and is very suitable for protecting valuable digital images in the current on-line monitoring environment.

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