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A robust digital image watermarking based on adaptive multifunctional scheme

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ABSTRACT

Reversible watermarking is mostly fragile, it can restore the original image losslessly if there is no attack during transmission. However, in real life, it is impossible not to be attacked completely. Reversible watermarking loses reversibility and becomes meaningless if it is attacked maliciously. In order to overcome this drawback and broaden its application field, an adaptive multifunctional watermarking scheme is proposed which is a special reversible watermarking scheme, which can not only restore the original image losslessly when it meets no attacks, but also can approximately recover the original image when it encounters malicious attacks. In the paper, the original image is divided into non-overlapping 8×8 blocks. And then, each block is transformed by IDCT (Integer Discrete Cosine Transform). The recovery watermark is generated by the method of 2DPCA (2 Dimension Principal Component Analysis) and the authentication watermark is produced by the special algorithm. According to the proposed block mapping method, the watermarks are embedded into its far mapping block adaptively. Moreover, MC (mapping and compensation) method is proposed to avoid overflow and underflow problems. The experimental results show that the proposed scheme can achieve reversibility and recoverability while keeping the lower distortion and higher embedding capacity.

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1. Introduction

With the rapid development of internet and multimedia technologies, it is easy to distribute and manipulate the digital products. Digital watermarking is an important method for traditional encryption measures, which can effectively protect the copyrights of digital products [1,2]. Most conventional watermarking schemes are loss, after watermark embedding, it will produce a permanent distortion to the original image, and it is impossible for the original image to restore losslessly. However, in some fields, such as medical, military and legal fields, the requirements for the quality of images are rigidly demanded. They require absolute precision, any slightest permanent distortion is unacceptable. Reversible watermarking is presented to meet such needs [3], which means that watermarked images can be restored to original ones losslessly as well as the watermarks. Reversible watermarking is widely used, so it has placed a great emphasis on information science [3–19]. However, there is an important premise to achieve the reversible watermarking, that is, it can't be affected or attacked during transmission. However, in real life, it is difficult for the image not to be affected or attacked completely, which limits the practical application of the reversible watermarking. So putting forward a multifunctional watermarking scheme is necessary. Multifunctional watermarking scheme can not only achieve reversibility under the no attack situation, but also can recover the original image approximately under attacks.

So far, most of the reversible watermarking algorithm has only reversibility. Once it is affected or attacked during transmission, it can't restore the original image losslessly, which loses its application value. Usually conventional reversible watermarking approaches consist of two main categories, one is histogram-shifting based methods and the other is difference expansion based methods. Ni et al. presents a histogram-shifting based method to embed watermark reversibly [9]. In this work, a watermark bit 1 is embedded by adding the peak-pixel value in histogram, while embedding a 0 involved no modification. However, the information of the peak point is required in the procedure of extracting the watermark and recovering the original image. To solve this

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problem, Tai et al. proposes a binary tree structure that can be used to pre-determine the peak point used for embedding watermarks [11]. It does not only adopt a histogram shifting technique to prevent overflow and underflow, but also achieve large embedding capacity while keeping the distortion low. Tian proposes reversible watermark scheme based on difference expansion [5], which embedded 1 bit watermark into the LSB of the difference between two pixels. The new calculated difference is then added to these two selected pixels as embedding steps. In Ref. [16], the prediction error expansion technique is further investigated and an efficient reversible watermarking scheme is proposed. This scheme presents incorporation adaptive embedding and pixel selection which adaptively embeds 1 or 2 bit into expandable pixels according to the local complexity. However, its embedding capacity is low and it cannot control the capacity. To solve this problem, Raman et al. adopts two new techniques of Embedded Zerotree Wavelet and Bit-plan Complexity Segmentation to embed data [17]. It divides the image into flat region and rough region, then selects the flat region to embed data and leaves the rough region unchanged. It does not only avoid expanding pixel with huge prediction errors but also reduce embedding impact and achieve a better visual quality watermarked image. Lee et al. proposes an adaptive lossless stegano-graphics scheme with centralized difference expansion [10]. In this method, the original image is segmented to $m \times n$ blocks and differences between pixels in each block are used to embed watermarks. However, it will lose reversibility when it encounters malicious attack.

All above reversible watermarking schemes are fragile and achieve only reversible function under the condition of no attacks. Once they encounter malicious attack, they will lose reversibility and become meaningless. To overcome it and broaden its application field, this paper proposes a multifunctional watermarking scheme which has different functions under the different circumstance. It can also be called a special reversible watermarking scheme based on difference expansion which means that the proposed method can restore the original image from the watermarked image losslessly when there is no attack, and it also can approximately recover original image by dual watermark when it encounters malicious attacked. Reversibility and recoverability broaden its application field and actual value. The proposed scheme divides the image into non-overlapping 8×8 blocks, and then identifies the corresponding relation between block and its mapping block. The recovery watermark of each block is embedded into its mapping block adaptively. When embedding, the blocks of size 8×8 may be divided into 4×4 or 2×2 according to their block structures. If possible, the differences between central ordered pixel and other ordered pixels in each block are expanded to embed watermarks. When the watermarked image is attacked maliciously, it will produce a permanent distortion. We can use the authentication watermark to detect the tampered region, and use the recovery watermark to recover the original image approximately.

The rest of the paper is organized as follows. Section 2 provides an introduction of IDCT and 2DPCA. Section 3 describes the proposed adaptive multifunctional watermarking scheme. Experimental results and comparisons are given in Section 4, and Section 5 draws a brief conclusion.

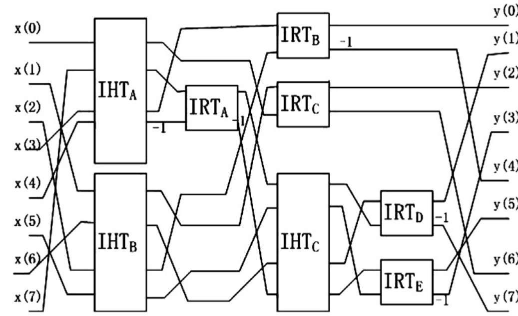

Fig. 1. Butterfly algorithm of 8×8 IDCT (Integer Discrete Cosine Transformation).

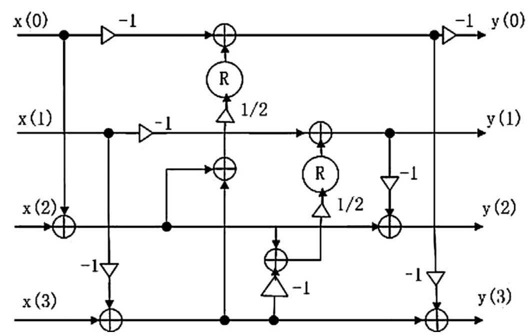

Fig. 2. The algorithm diagram of IHT (Integer Hadanard Transform).

2. The introduction of IDCT and 2DPCA

2.1. IDCT

IDCT (Integer DCT) [20] is composed of IHT (Integer Hadanard Transform) and IRT (Integer Rotation Transform). Butterfly algorithm of 8×8 IDCT is illustrated in Fig. 1. The IDCT transforms integer input vector into integer output vector. Therefore it achieves effective lossless coding applying entropy coding directly to the output vector.

The IHT contains rounding operations "R" in the lifting structure. "R" is a key part for an integer-to-integer transform. The IHT is illustrated by Fig. 2 and the following equation.

$$\begin{pmatrix} -y(0) \\ y(1) \\ y(2) \\ y(3) \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 1/2 & 1/2 \\ 0 & 1 & 1/2 & -1/2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & -1 & 0 & 1 \end{pmatrix} \begin{pmatrix} x(0) \\ x(1) \\ x(2) \\ x(3) \end{pmatrix} \quad (1)$$

IRT as indicated in Fig. 3 has five IRTs and each IRT has three multipliers. Therefore, the IDCT has 15 multipliers in total. The IRT is defined by the following equations.

$$\begin{pmatrix} y(0) \\ y(1) \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ m_{3(i)} & 1 \end{pmatrix} \begin{pmatrix} 1 & m_{2(i)} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ m_{1(i)} & 1 \end{pmatrix} \begin{pmatrix} x(0) \\ x(1) \end{pmatrix} \quad (2)$$

$$\begin{aligned} M_A = M_B &= \left\lfloor 1 - 2^{1/2} \quad 2^{-1/2} \quad 1 - 2^{1/2} \right\rfloor, \\ M_C &= \left[\frac{\sin(\pi/8) - 1}{\cos(\pi/8)} \quad \cos(\pi/8) \quad \frac{\cos(3\pi/8) - 1}{\cos(\pi/8)} \right], \\ M_D &= \left[\frac{1 - \cos(3\pi/16)}{\sin(3\pi/16)} \quad -\sin(3\pi/16) \quad \frac{1 - \cos(3\pi/16)}{\sin(3\pi/16)} \right], \\ M_E &= \left[\frac{\cos(\pi/16) - 1}{\sin(\pi/16)} \quad \sin(\pi/16) \quad \frac{\cos(\pi/16) - 1}{\sin(\pi/16)} \right], \end{aligned} \quad (3)$$

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