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A blind dual color images watermarking based on IWT and state coding

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ABSTRACT

In this paper, a state-coding based blind watermarking algorithm is proposed to embed color image watermark to color host image. The technique of state coding, which makes the state code of data set be equal to the hiding watermark information, is introduced in this paper. When embedding watermark, using Integer Wavelet Transform (IWT) and the rules of state coding, these components, R, G and B, of color image watermark are embedded to these components, Y, Cr and Cb, of color host image. Moreover, the rules of state coding are also used to extract watermark from the watermarked image without resorting to the original watermark or original host image. Experimental results show that the proposed watermarking algorithm cannot only meet the demand on invisibility and robustness of the watermark, but also have well performance compared with other proposed methods considered in this work.

1. Introduction

Due to the rapid growth of the Internet and the extensive evolution of digital technologies, the availability of digital multimedia content, e.g., image, audio and video, has sharply increased. Accompanied is the easily copied of multimedia data, even illegally distributed through the Internet. Hence, how to protect the copyright of digital multimedia is becoming more and more important. Among those exiting copyright protect methods, digital watermarking has been widely approved [1,2]. The feature of digital watermarking is to allow for the imperceptibly embedding information in an original multimedia data.

In the recent years, color image watermarking has been becoming one of the research hot topics [3–6]. Compared with gray level watermarking, the color one has two advantages: (1) to hide more amount of data; (2) to attain higher fidelity, which is because the color perception depends not only on the luminance but also on the chrominance. Thus, by using color watermarking, both the capacity and the fidelity can be increased, relative to gray level watermarking [3]. For color image watermarking, the embedded watermark may be binary images [7–9] , gray scale images [4–6] , or color images [10–12]. It is usually termed as dual color image watermarking that both the original watermark and original host image are color. Among these existing dual color image watermarkings, a spatial-domain color image watermarking scheme was proposed in ref. [10], in which color watermarks were carried by the quantization indices of the host image in the uniform color space. Although the watermarking scheme in ref. [10] had the features of simplicity in computation and implementation, the robustness of the color watermark was weaker. Zhan, et al. [11] presented a block DCT-based dual color image blind watermarking algorithm, and simultaneously modified both the AC and DC coefficients in Y, Cb and Cr layer of the original host color image, which would inevitably affect the invisibility and robustness of watermark robustness. The watermarking in ref. [12] can attain a blind color image extraction watermarking, one or more singular values must be modified to keep the order of singular values that degrade the quality of the watermarked image in some extent. It should be pointed out that with the increasingly popularity of Internet, color images with larger amounts of data are gradually being applied as visual watermarks.

As well known, an effective watermarking scheme should have some better performance in terms of robustness [13], imperceptibility [14], and capacity [15]. In general, these above properties are conflict to each other [3]. For the color watermark, the better imperceptibility and the bigger capacity can be first realized, but it is difficult to further improve the robustness. Hence, how to improve the robustness for color watermarking is a difficult problem. Although the non-blind watermarking technology has better robustness than the blind ones [16], it is not convenient to extract watermark since the original host image and original watermark are required.

As well known, the integer wavelet transform (IWT) can map integer to integer without the rounding error, and can obtain good imperceptibility [17]. There are many IWT-based watermarking schemes been proposed in recent years [18–20]. In the existing watermarking based on IWT, most of them have been focused on the semi-fragile watermarking and the host image is gray-level image, only a few of

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watermarking scheme were applied to color image. For example, a blind self-authentication of images was proposed based on the lifting-based integer wavelet transform to detect the tampering in the host image [18]. In ref. [19], a multiple logo-watermarking scheme based on integer wavelet for copyright protection of digital gray-level image is presented. For protect the copyright of color image, a novel blind watermarking algorithm based on the IWT was proposed to embed binary image in color image [20].

In this paper, a blind dual color images watermarking based on Integer Wavelet Transform (IWT) and state coding is proposed. On the one hand, this work will utilize IWT technique to enhance the robustness of watermark. On the other hand, it will be seen later that the state coding technique can make the state code of data set be equal to the hiding watermark information, which cannot only ensure the blind detection, but also enhance the watermark capacity. Therefore, this work will utilize state coding method to embed color image watermark into the color host image. The experiment results show that both the invisibility and robustness requirements for watermarking are well satisfied in the proposed scheme.

The rest of this paper is organized as follows. The technique of state coding and the IWT are described in Section 2. The detailed watermark embedding and extraction procedure are presented in Sections 3 and 4, respectively. Section 5 gives the experimental results. Finally, the conclusions are given in Section 6.

2. Preliminary

2.1. State coding technique

It is well known that the color image has more information than the binary or gray image. Hence, we must consider how to increase the watermark capacity and fulfill the purpose of blind extraction when embed color watermark image in color image. To this end, in this work, we propose a new state coding method to embed and extract watermark information. The main procedure of state coding includes four steps as follows.

(1) Calculating the state code of data set A by Eq. (1). For a set of integer data $A=\{a_i, 1\le i\le n\}$, their state code will be obtained by Eq. (1).

$$s = \mathrm{mod}\left(\sum_{i=1}^{n}(a_i \times i), r\right) \tag{1}$$

where r is the number base of a_i. For example, the data set is $(12, 34, 56)_{10}$, let r be 10, then its state code s is 8.

(2) Calculating the difference between the state code s and the watermark information w by Eq. (2).

$$e = \mathrm{mod}((w-s), r). \tag{2}$$

(3) Modifying the data a_e to embed the watermark information w and get new data set A^*.

(4) Repeating (1)–(3), until the state code of A^* equals to the w.

In this work, the proposed state coding can be used to embed a watermark character with decimal base into one data set that includes five decimal integers. Because any integer has two changes, i.e., increase or decrease, the n integers at most have $2n$ states when any of integers is increased or decreased with 1. We use the different states to present the watermark information w, $w\in\{0,1,\ldots,9\}$, here w includes ten states. Additionally, in the decimal base, the data is expressed with ten Arabic numbers, i.e., 0, 1,…, 9, which equals to the state of watermark information. Therefore, each data set that includes five decimal numbers can hide a watermark character with decimal base, which enhances the capacity of watermarking. Moreover, only the watermarked image is required to extract watermark without resorting to the original host image or original watermark image. The detailed application of state coding can be found in Section 3.

2.2. Integer wavelet transform

The existing watermarking algorithms based on the traditional wavelet transform are not suitable for the color image due to the disadvantages of computational complexity and rounding error. Since the color image has great amount of information and its pixel values are integers, the integer wavelet transform may directly map the pixel value to integer without any rounding error and can quickly finish the watermarking algorithm [17].

The main procedure of IWT includes three steps as follows:

(1) Split: the original signal c_k^j is divided into two different parts: even sequence e_k^{j-1} and odd sequence o_k^{j-1}:

$$e_k^{j-1} = c_{2k}^j, o_k^{j-1} = c_{2k+1}^j. \tag{3}$$

(2) Predict: according to the correlation between the data, the odd sequence is predicted by the even sequence e_k^{j-1} and a prediction operator P, and the difference between the odd sequence o_k^{j-1} and the prediction results $P(e_k^{j-1})$ will be viewed as the high-frequency coefficient of next-level IWT and instead the original odd sequence, i.e.,

$$O_k^{j-1} = o_k^{j-1} - P\left(e_k^{j-1}\right), \tag{4}$$

where O_k^{j-1} presents the predicted difference, that is the new odd sequence, P is the prediction operator, the prediction sequence must reflect the data correlation.

(3) Update: in order to keep the same feature of even sequence e_k^{j-1}, the updating operator U is used to calculate O_k^{j-1}, and then update the original even sequence, that is,

$$E_k^{j-1} = e_k^{j-1} + U\left(O_k^{j-1}\right), \tag{5}$$

where E_k^{j-1} is the updated even sequence. After the IWT, the even sequence is the low-frequency component, the odd sequence is the high-frequency and the low-frequency component can be furthermore transformed by the same procedure.

3. Watermark embedding

The coding for color watermark image is an important step, which will directly affect the quality of watermarking. In order to embed the watermark, the color watermark image is firstly divided into three components: red (R), green (G) and blue (B). Moreover, the Hash permutation based on private key K is applied to rearrange the pixel values of each component, which will enhance the security and robustness of watermark. In this work, based on the IWT, the state coding is utilized to embed the color image watermark and extract the watermark without the requirements of original host image and original watermark, which is different from some aforementioned color watermarking methods. For example, in the spatial-domain watermarking method [10], both the embedding and extraction of color watermarks are accomplished by color quantization and the original color table and color gamut are required in the procedure of watermarking extraction. In ref. [12], one or more single values will be modified for embedding a watermark information, which will result in more change for the whole image pixel values, while the proposed