Optik 124 (2013) 6255–6260

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

A blind color image watermarking based on DC component in the spatial domain

Qingtang Su [a,b,*], Yugang Niu [b], Qingjun Wang [a], Guorui Sheng [a]

[a] School of Information Science and Engineering, Lu Dong University, Yantai 264025, PR China
[b] Key Laboratory of Advanced Control and Optimization for Chemical Process, Ministry of Education, East China University of Science and Technology, Shanghai 200237, PR China

ARTICLE INFO

Article history:
Received 9 December 2012
Accepted 1 May 2013

Keywords:
Image watermarking
Direct current coefficient
Spatial domain
Discrete cosine transform
Color image

ABSTRACT

Color image watermarking has become essential and important copyright protection or authentication scheme. It is noted that most of the existing color image watermarking algorithms are performed only in the single domain (spatial domain or frequency domain), and not to integrate these merits of the different domains. By utilizing the generating principle and distribution feature of the direct current (DC) coefficient, a novel blind watermarking algorithm is proposed for color host images in this paper. Firstly, the Y luminance of host image is divided into 8 × 8 sub-blocks and the DC coefficients of each block are directly calculated in the spatial domain without DCT transform. Secondly, according to the watermark information and the quantization step, the DC coefficients are calculated and their increments are further utilized to modify directly the values of all pixels in the spatial domain instead of the DCT domain to embed watermark. When watermark extraction, only the watermarked image and the quantization step are needed in the spatial domain. Experimental results show that the proposed method not only can resist both traditional signal processing attacks and geometric attacks, but also has more efficient in computational complexity. Comparisons also demonstrate the advantages of the method.

1. Introduction

With the rapid growth of Internet and digital media techniques, people can easily transmit, store and process multimedia data, such as images, video, and audio recordings. Therefore, the ownership protection of multimedia data has become more and more important. Hence, the technology of image watermarking has recently attracted increasing interests [1,2]. The basic idea of digital watermarking technique is to embed a watermark or a metadata containing information relative to the protected multimedia host data into the host data. This information could be the copyright, timestamp or any other useful information. By detecting the watermark from the watermarked data, the ownership or copyright of the host data can also be proven. For the requirements of actual application, a watermarking system has some essential features, such as imperceptibility (or invisibility), robustness, and so on.

In recent years, many watermarking schemes have been proposed, which can be roughly classified into two categories: frequency domain and spatial domain.

For the frequency domain techniques, the host image is first converted into the new domain by utilizing various transformation methods, such as discrete Fourier transform (DFT), discrete cosine transform (DCT) or discrete wavelet transform (DWT). The coefficients in frequency domain are further altered to embed the watermark. In order to achieve better robustness against attacks, many watermarking schemes in the frequency domain have been developed see [3–11] and the reference therein. The key feature of frequency domain algorithm is of stronger robustness. For example, Vahedi et al. [3] proposed a new DWT-based watermarking method using bio-inspired optimization principles; relatively, this method has better robustness but the genetic algorithm was used to cause the computation complexity was higher. DFT-based algorithms have stronger robustness to translation, rotation, and scaling attacks [4,5]. That is because Fourier coefficients in DFT-based algorithm have two components, phase and magnitude, and the attacks, such as geometric rotation, do not modify the phase information of the coefficients. Similarly, other watermarking algorithms in frequency domain such as DCT-based algorithm [6–8] and DWT-based algorithm [9–11] were also shown to have stronger robustness to JPEG compression.

On the other hand, the basic idea of the spatial domain watermarking is to modify directly the pixel values. That brings some advantages such as simpler, lower computational complexity, etc., but also result in its lower security and weaker robustness

* Corresponding author at: School of Information Science and Engineering, Lu Dong University, Yantai 264025, PR China. Tel.: +86 535 6693309.
E-mail address: sdytsqt@163.com (Q. Su).

0030-4026/$ – see front matter
http://dx.doi.org/10.1016/j.ijleo.2013.05.013

to signal processing attacks. That is because LSB planes are apt to be replaced by random bits such that the watermark bits may be removed [12]. To improve the robustness of spatial domain watermarking techniques, some block-based methods instead of pixel have been proposed. For instance, Nasir et al. [13] presented a multiple digital watermarking technique for the copyright protection of digital color images, in which a binary watermark image was divided into four parts and embedded into different regions of the blue component of the color image in the spatial domain.

As shown in the above discussion, either frequency domain or spatial domain has some features. Now, we had to ask: Whether may the features of the two techniques be integrated to attain better watermarking? This paper will probe the problem. It will be shown that it is feasible to embed the watermark into DC component of the DCT domain and further realize it in the spatial domain. It is noted that Shih and Wu [14] proposed a method based on the combination of spatial domain and frequency domain, in which the watermark image was split into two parts, respectively, for spatial and frequency insertion according to the user's preference and data importance. However, the method in [14] did not truly combine the advantages of spatial domain and frequency domain, since the scheme was selected, respectively, either in the frequency domain or in the spatial domain under different conditions.

It is worthy of noting that the essence of watermarking in frequency domain is to distribute the energy of embedded signal over all pixels in the spatial domain. This means that one can utilize this feature to achieve the function of the frequency domain by directly updating the pixel value in the spatial domain. Based on the above discussion, the paper proposes a novel blind watermarking algorithm for color host images. By utilizing the generating principle and distribution feature of the DC coefficient, the proposed algorithm directly computes the DC coefficient in the spatial domain. Furthermore, the values of pixels can be properly modified in the spatial domain according to the watermark information and the quantization step. Besides, one may attain the purpose of updating the DC coefficient in the DCT domain and finishing the watermarking procedure. The proposed scheme not only keeps the distribution feature of frequency coefficients, but also avoids the errors resulting from the frequency transformation. Hence, the proposed watermarking is simpler and higher efficiency.

The rest of this paper is organized as follows. In Section 2, the modifying technique of DC coefficient in spatial domain is introduced. Section 3 gives the details of the proposed algorithm, which includes watermark generation, watermark embedding and watermark extraction. The experimental test of the proposed algorithm is performed in Section 4, which is followed by the conclusions in Section 5.

2. The technique of modifying DC coefficient in spatial domain

2.1. Obtaining DC coefficient in the spatial domain

DCT is a kind of domain transformation methods for real number, whose transform kernel is the cosine function. DCT has a wide application in digital watermarking. By means of 2-D DCT transform, an image can be converted from the spatial domain to the DCT domain. Similarly, the image can also be restored from the DCT domain to the spatial domain via the 2-D inverse DCT.

For a $M \times N$ image $f(x, y)$ ($x = 0, 1, 2, \ldots, M-1$, $y = 0, 1, 2, \ldots, N-1$), its 2-D DCT is given as follows:

$$C(u, v) = \alpha_u \alpha_v \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \cos\frac{\pi(2x+1)u}{2M} \cos\frac{\pi(2y+1)v}{2N} \tag{1}$$

where M and N are the row and column size of $f(x, y)$, u and v are the horizontal and vertical frequency ($u = 0, 1, 2, \ldots, M-1$, $v = 0, 1, 2, \ldots, N-1$), $C(u, v)$ is the DCT coefficient of image $f(x, y)$,

$$\alpha_u = \begin{cases} \sqrt{1/M}, & u = 0 \\ \sqrt{2/M}, & 1 \le u < M-1 \end{cases}, \quad \alpha_v = \begin{cases} \sqrt{1/N}, & v = 0 \\ \sqrt{2/N}, & 1 \le v < N-1 \end{cases} \tag{2}$$

Similarly, the inverse DCT of the image $f(x, y)$ is described by

$$f(x, y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \alpha_u \alpha_v C(u, v) \cos\frac{\pi(2x+1)u}{2M} \cos\frac{\pi(2y+1)v}{2N} \tag{3}$$

From Eq. (1), the DC coefficients in the DCT domain can be obtained by

$$C(0, 0) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \tag{4}$$

It is shown from Eq. (4) that DC coefficient $C(0,0)$ can be obtained directly by a simple averaged sum of all pixel values of $f(x, y)$ in the spatial domain.

2.2. The relationship between DCT domain and spatial domain

The general procedure of watermarking in the DCT domain is to add watermark information on the DCT coefficients, and then obtain the watermarked image via the inverse DCT. In the following content, we will prove that the energy of signal added to DC coefficient has not any loss after the inverse DCT. That means the procedure of embedding watermark into the DC coefficient in DCT domain can be replaced in the spatial domain.

While a single $E(i, j)$ is added to one of these coefficients $C(i, j)$ in the (i, j) of DCT domain, these coefficients will become $C'(i, j)$ as follows:

$$C'(i, j) = C(i, j) + E(i, j) \tag{5}$$

with $i = 0, 1, 2, \ldots, M-1$, $j = 0, 1, 2, \ldots, N-1$.

It is assumed that the energy E_d of $E(i, j)$ is given as

$$E_d = E^2(i, j) \tag{6}$$

All of the modified coefficients of $f(x, y)$ are calculated via the inverse DCT:

$$\begin{aligned} f'(x, y) &= \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \alpha_u \alpha_v C'(u, v) \cos\frac{\pi(2x+1)u}{2M} \cos\frac{\pi(2y+1)v}{2N} \\ &= \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \alpha_u \alpha_v C(u, v) \cos\frac{\pi(2x+1)u}{2M} \cos\frac{\pi(2y+1)v}{2N} \\ &\quad \alpha_i \alpha_j E(i, j) \cos\frac{\pi(2x+1)i}{2M} \cos\frac{\pi(2y+1)j}{2N} \\ &= f(x, y) + e(i, j) \end{aligned} \tag{7}$$

where

$$e(i, j) = \alpha_i \alpha_j E(i, j) \cos\frac{\pi(2x+1)i}{2M} \cos\frac{\pi(2y+1)j}{2N} \tag{8}$$