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A geometric correction based robust color image watermarking scheme using quaternion Exponent moments☆

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ABSTRACT

Most of the existing color image watermarking schemes was designed to mark grayscale images or use the color components, which ignore the significant correlation between different color channels. Recently, several approaches were developed to process the color channels intrinsically, but they always cannot counterattack geometric distortions. It is a challenging work to design a robust color image watermarking scheme against geometrical distortions. In this paper, we propose a geometric correction based robust color image watermarking approach using quaternion Exponent moments (QEMs). The novelty of our approach is that (1) the QEMs are derived to deal with the color images in a holistic manner, and (2) the QEMs are exploited for estimating the geometric distortions parameters in order to permit watermark extraction. Experimental results confirm the validity of our approach and its higher robustness against geometrical distortions compared to alternative watermarking methods in the literature.

1. Introduction

The rapid development of new information technologies has improved the ease of access to digital information. It also leads to the problem of illegal copying and redistribution of digital media. Hence, the protection of intellectual property becomes more and more attentive and important for the society. The concept of digital watermarking came up while trying to solve the problems related to the management of intellectual property of media. Generally, digital watermarking is the technology of embedding information (watermark signal) into the multimedia data (such as video, image, audio, and text), called host signal or cover signal, in order to produce watermarked signal for use in certain applications such as copyright protection, content authentication, copy protection, broadcast monitoring, and so on. For different purposes, digital watermarking has been branched into two classifications: robust watermarking technique and fragile watermarking technique. Robust digital watermarking is used to protect ownership of the digital media. In contrast, the purpose of fragile watermarking technique is digital media authentication, that is, to ensure the integrity of the digital media [1,2].

In the last decade, there has been an unprecedented development in the robust image watermarking field, but most of the existing watermarking schemes were designed to mark grayscale images [3–7]. Color image is more common in our everyday life, and can provide more information than grayscale image, so it is very important to embed the digital watermark into color image for copyright protection.

With the introduction of color imaging, several alternatives have been suggested to apply watermarking techniques to color images, but they were mainly designed to mark grayscale images or use the color components [8]. Al-Otum et al. [9] extended the pixel-wise masking watermarking technique to color image, and embedded the digital watermark in the Y component of the YCbCr model. Hussein et al. [10] proposed a non-blind luminance-based color image watermarking technique. The original 512×512 color host image is divided into 8×8

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blocks, then each block is converted to YCbCr color space, and finally the watermark is embedded into the Y component of each block. Liu et al. [11] presented a wavelet-based watermarking scheme for color images. The watermarking scheme is based on the design of a color visual model, which is the modification of a perceptual model used in the image coding of gray scale images. The model is to estimate the noise detection threshold of each wavelet coefficient in luminance and chrominance components of color images in order to satisfy transparency and robustness required by the color image watermarking technique. Findik et al. [12] suggested a watermarking technique that uses artificial immune recognition system to protect color image's intellectual property rights. The watermark is embedded in the blue channel of a color image. M-bit binary sequence embedded into the color image is used to train artificial immune recognition system. With this composed technique, extracting the watermark which is embedded into the color image, is carried out using artificial immune recognition system. Basso et al. [13] presented a method for blind digital watermarking of color images. The proposed scheme performed a decorrelation of the RGB color bands of the image to be watermarked using a Karhunen–Loève transform (KLT), and then marked the coefficients of the KLT of the first band obtained. Su et al. [14] proposed a state-coding based blind color image watermarking algorithm, in which the R, G, and B components of color image watermark are embedded to the Y, Cr and Cb components of color host image respectively. Dejey et al. [15] introduced two color image watermarking using the combined discrete wavelet transform-fan beam transform (DWT-FBT). The two schemes proposed in the combined domain are (i) wavelet fan beam watermarking on luminance and chrominance and (ii) wavelet fan beam watermarking on chrominance alone. Tsai et al. [16] proposed a watermarking technique called SVM-based color image watermarking (SCIW) for the authentication of color images. The SCIW method utilizes the set of training patterns to train the SVM and then applies the trained SVM to classify a set of testing patterns. Following the results produced by the classifier, the SCIW method retrieves the hidden watermark without the original image during watermark extraction. Chou et al. [17] proposed a color image watermarking scheme, which is perceptually optimized by embedding high-strength watermark signals in wavelet coefficients of high perceptual redundancy. The strength of the embedded watermark signal is determined by the amount of perceptual redundancy inherent in the corresponding wavelet coefficient. Peng et al. [18] presented a color image watermarking method in multiwavelet domain based on support vector machines (SVMs), in which the special frequency band and property of image in multiwavelet domain are employed. Hazem et al. [19] proposed a wavelet-based blind technique for color image watermarking by using self-embedded color permissibility (CIW-SECP). The CIW-SECP technique is based on embedding two watermarks in a spread-spectrum fashion in the U and V planes of the YUV color space. Verma et al. [20] proposed a wavelet based color image watermarking scheme, which utilizes a specific version of gamma corrected YCbCr color space. To achieve both robustness and imperceptibility to the maximum possible extent, the watermark payload is divided into two parts. A smaller part with less embedding strength is embedded in Y channel, and the other larger part with higher embedding strength is embedded in Cr channel. Niu et al. [21] described a blind color image watermarking approach by using the support vector regression (SVR) and nonsubsampled contourlet transform, in which the watermark was embedded into the Green channel of the host image. Imran et al. [22] proposed a new color image watermarking scheme, in which a color watermark is embedded into a color image. Principle component analysis is used to uncorrelate the R, G and B channels of both the images. Each channel of color watermark is embedded into singular values of corresponding channel of cover image after discrete wavelet decomposition. Kwitt et al. [23] presented a novel watermark detector for additive spread-spectrum watermarking in the wavelet transform domain of color images. They propose to model the highly correlated DWT subbands of the RGB color channels by multivariate power-exponential distributions. This statistical model is then exploited to derive a likelihood ratio test for watermark detection. Gunjal et al. [24] proposed a DWT-SVD based color image watermarking technique in YUV color space. The RGB color image is converted into YUV color space. Image is decomposed by 3 level DWT and then SVD is applied. The watermark is embedded in all Y, U and V color spaces in HL3 region.

The above-mentioned color image watermarking schemes all ignore the significant correlation between different color channels, and the performance of the watermarking system will be affected inevitably. To overcome this problem, researchers have started to propose models to process the color channels intrinsically. Al-Otum et al. [25] introduced a blind watermarking technique based on the so called wavelet-trees. The proposed technique deals with the color pixel as one unit and exploits the significant features and relations between the color pixel components in the wavelet domain. The watermark is embedded by spreading it through the host image in such a manner that the inter-pixel robust relations carry the watermark bit sign with sufficient energy. Bas et al. [26] proposed a digital color image watermarking scheme using the hypercomplex numbers representation and the quaternion Fourier transform (QFT). Tsui et al. [27] proposed a nonblind color image watermarking method, which requires the original image for watermark extraction. The method encodes the $L^*a^*b^*$ components of color images and watermarks are embedded as vectors in the frequency domain of the channels by using the QFT. These color image watermarking methods consider the correlation between different color channels, but they always can not counterattack geometric distortions.

According to quaternion Exponent moments (QEMs) and least squares support vector machine (LS-SVM), a new blind color image watermarking approach is proposed, which has good robustness against geometric distortions. The novelty of our approach is that (1) the QEMs are derived to deal with the color images in a holistic manner, and (2) the QEMs are exploited for estimating the geometric distortions parameters in order to permit watermark extraction.

The rest of this paper is organized as follows. Section 2 recalls some preliminaries about the quaternions and Exponent moments (EMs). In Section 3, the definition of QEMs is presented, and the relationship between the QEMs and the conventional EMs is analyzed. Section 4 discusses the geometric correction based robust color image watermarking approach using QEMs. Simulation results in Section 5 will show the performance of our scheme. Finally, Section 6 concludes this presentation.

2. Preliminaries

2.1. Quaternion representation of a color image

Quaternions, a generalization of the complex numbers, were introduced by the mathematician Hamilton in 1843 [28]. A quaternion consists of one real part and three imaginary parts as follows:

$$q = a + b\mathbf{i} + c\mathbf{j} + d\mathbf{k}$$