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A robust blind color image watermarking in quaternion Fourier transform domain

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ABSTRACT

Most of the existing color image watermarking schemes were designed to mark the image luminance component only, which have some disadvantages: (i) they are sensitive to color attacks because of ignoring the correlation between different color channels, (ii) they are always not robust to geometric distortions for neglecting the watermark desynchronization. It is a challenging work to design a robust color image watermarking scheme. Based on quaternion Fourier transform and least squares support vector machine (LS-SVM), we propose a robust blind color image watermarking in quaternion Fourier transform domain, which has good visual quality. Firstly, the original color image is divided into color image blocks. Then, the fast quaternion Fourier transform is performed on the color image block. Finally, the digital watermark is embedded into original color image by adaptively modulating the real quaternion Fourier transform coefficients of color image block. For watermark decoding, the LS-SVM correction with pseudo-Zernike moments is utilized. Experimental results show that the proposed color image watermarking is not only robust against common image processing operations such as filtering, JPEG compression, histogram equalization, and image blurring, but also robust against the geometrical distortions.

1. Introduction

Because of the rapid advance of network technology, humans can arbitrarily and easily access or distribute any multimedia data from networks. Hence, the protection of intellectual property becomes more and more attentive and important for the society. Based on this scheme, many methods are being developed (Cheddad et al., 2010; Huang et al., 2010). Digital watermarking is a favorable method for copyright protection of multimedia. It is a digital code embedded in the host data and typically contains information about origin, status, and/or destination of the data. A digital watermark is an identification code that carries information about the copyright owner, the creator of the work, the authorized consumer, etc. It is permanently embedded into the digital data for copyright protection and may be used to check whether the data have been illegally modified (Cheddad et al., 2010; Huang et al., 2010). 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.

In the last decade, there has been an unprecedented development in the robust image watermarking field. On the other hand, attacks against image watermarking systems have become more sophisticated (Kumar and Santhi, 2011; Sadasivam et al., 2011). In general, these attacks on watermarking systems can be categorized into noise-like common image processing operations and geometric distortions. While the noise-like common image processing operations, such as lossy compression, noise addition, histogram equalization, and light increasing, reduces watermark energy, geometric distortions can induce synchronization errors between the extracted watermark and the original watermark during the detection, even though the watermark still exists in the watermarked image.

According to quaternion Fourier transform and least squares support vector machine (LS-SVM), a robust blind color image watermarking in quaternion Fourier transform domain is proposed, which has good visual quality. Firstly, the original color image is divided into color image blocks. Then, the fast quaternion Fourier transform is performed on the color image block. Finally, the digital watermark is embedded into original color image by adaptively modulating the real quaternion Fourier transform coefficients of color image block. The main steps of digital watermark detecting procedure include: (1) fast quaternion Fourier transform is performed on the training images, which produces a real coefficient matrix and three imaginary coefficient matrices, (2) some

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low-order pseudo-Zernike moments of the real coefficient matrix are computed, which are regarded as the effective feature vectors, (3) the appropriate kernel function is selected for training, and a LS-SVM training model can be obtained, (4) the watermarked color image is corrected with the well trained LS-SVM model, and (5) the digital watermark is extracted from the corrected watermarked color image. The experimental results show the outstanding robustness of the proposed scheme against different common image processing operations and geometrical distortions.

The rest of this paper is organized as follows. A review of previous related work is presented in Section 2. Section 3 describes the fast quaternion Fourier transform of color images. Section 4 introduces basic theory about LS-SVM. Section 5 contains the description of our watermark embedding procedure. Section 6 covers the details of the watermark detection procedure. Simulation results in Section 7 will show the performance of our scheme. Finally, Section 8 concludes this presentation.

2. Related work

Nowadays, several approaches that counterattack geometric distortions have been developed. These schemes can be roughly divided into exhaustive search, invariant transform, geometrical correction, and feature-based algorithms (Kumar and Santhi, 2011; Zheng et al., 2007; Muhammad, 2011).

***Exhaustive search*:** The simplest method for watermark detection after geometric distortions is an exhaustive search. This approach consists simply in inverting each hypothetical geometric deformation that might have been applied to the watermarked image, and then applying the watermark detector once for each possible distortion parameter. Obviously, this method is feasible for a restricted number of hypothetical deformations (e.g., scaling, rotation, translation), but it rapidly becomes intractable as the number of possible distortions increases. Furthermore, it tends to largely increase the false positive probability (Muhammad, 2011; Valizadeh and Wang, 2011).

Invariant transform: Another solution consists in embedding the watermark in a geometrical invariant subspace. In Jung et al. (2011), Kang et al. (2010), Wang and Hou (2010) and Rastegar et al. (2011), the watermark was embedded in an affine-invariant domain by using Fourier-Mellin transform, generalized Radon transform, geometric moments, singular value, and histogram shape respectively. Zhang et al. (2011) proposed a new watermarking approach which allows watermark detection and extraction under affine transformation attacks. The novelty of the approach stands on a set of affine invariants derived from Legendre moments. Watermark embedding and detection are directly performed on this set of invariants. These moments can be exploited for estimating the geometric distortion parameters in order to permit watermark extraction. In practice, this solution can be implemented for simple affine transformations, but it is inapplicable as soon as the image undergoes local geometrical deformations. Moreover, problems of approximation due to the discrete nature of the images, plus the reduction of the embedding space make the watermark weakly resistant to low-pass filtering and lossy compression.

Geometrical correction: Template correction is one of the most common resynchronization techniques, in which an additional watermark or template is inserted into the host image. Basically, this template is used as a reference to detect and compensate for geometrical deformations such as affine transforms. By focusing on a simple example, Barni (2005) investigated the effectiveness of exhaustive watermark detection and resynchronization through template matching against geometric distortions. Liu et al. (2007) presents an image rectification scheme that can be used by any image watermarking algorithm to provide robustness against rotation, scaling and translation (RST). In the watermarking, a small block is cut from the log-polar mapping (LPM) domain as a matching template, and a new filtering method is proposed to compute the cross-correlation between this template and the magnitude of the LPM of the image having undergone RST transformations to detect the rotation and scaling parameters. Qiu et al. (2011) proposed a robust image watermarking scheme. The scheme is composed of two parts: non-informative watermark embedded in b component of Lab color space, which is used to recover embedded region from the modified image; Informative watermark embedded in DCT domain that carries information can be used to protect copyright. This scheme is a blind watermarking scheme, extraction can be proposed without the presence of original image. In scheme (Kaur and Kaur, 2009), a watermarking technique is suggested that incorporates two watermarks in a host image for improved robustness. A watermark, in form of a PN sequence (information watermark), is embedded in the DCT domain of the cover image. The second watermark (synchronization template) is embedded in the already watermarked image. Synchronization template does not contain any information and is used only to detect and correct any geometrical changes came after the attack on the image. One major advantage of template corrections is their effectiveness to address synchronization of affine transformations, but this kind of pattern is unfortunately, for both watermarker and attacker, easily detectable in frequency domain. It is then relatively easy for a malicious party to remove these peaks, thus depriving the detector of any means of resynchronization.

Recently, some new geometrical corrections are introduced to the image watermarking domain. Liu and Huang (2008) presented a new robust watermarking scheme for color image by using scale invariant features transform image correction. In order to detect digital watermark, the scale invariant features of images are firstly extracted, and the match points between the watermarking image and the reference image are found. Then the watermarking image is corrected by affine transform of these match points. In approach (Nian et al., 2010), a definition of weight Hausdorff distance is defined. It is applied to evaluate the similarity between original and geometric distorted watermarking image. A fast divide and conquer strategy in six dimension is used to search the transformation parameters. The geometric distortion is corrected by the parameters. As a result, a distorted watermarking image could be corrected based on image feature. Wang et al. (2009) proposed a robust image watermarking detection algorithm against geometric distortions, in which the steady Krawtchouk moments are utilized. In scheme (Wu, 2009), in order to obtain the rotation, scaling and translation (RST) parameters, the support vector machine (SVM) are utilized to learn image geometric pattern represented by six combined low order image moments. The watermark extraction is carried out after watermarked image has been synchronized without original image.

Feature-based: The last class of resynchronization techniques uses image content to recover the watermark after geometrical transformations. Its basic idea is that, by binding the watermark with the geometrically invariant image features, the watermark detection can be done without synchronization error. Seo and Yoo (2006) introduce a content-based image watermarking algorithm based on scale-space representation. Gao et al. (2010) proposed a new image watermarking scheme on the basis of Seo's work (Seo and Yoo, 2006), which is insensitive to geometric distortions as well as common image processing operations. Wang et al. (2007) presented a feature-based digital image watermarking scheme in DFT domain. Lin et al. (2011) proposed a watermarking scheme that is robust to RST attacks, blind-detectable and has a reasonable embedding capacity. By embedding the message in the RST-invariant features of the image and introducing an human visible system (HVS)-based watermark embedding