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A new robust digital watermarking using local polar harmonic transform ☆

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ABSTRACT

Geometric distortions are more difficult to tackle than other types of attacks. It is a challenging work to design a robust image watermarking scheme against geometric distortions. In this paper, we propose a robust digital image watermarking scheme based on local polar harmonic transform. The proposed scheme has the following advantages: (1) the stable and uniform image feature points are extracted by the improved speeded-up robust feature (SURF) detector, in which the probability density gradient is utilized, (2) the affine invariant local feature regions are constructed adaptively according to the variation of local probability density, and (3) a new and effective 2D transform, named polar harmonic transform (PHT), is introduced to embed watermark in the digital image. Experiments are carried out on a digital image set of 100 images collected from Internet, and the preliminary results show that the proposed image watermarking is not only invisible and robust against common image processing operations such as filtering, noise adding, and JPEG compression, but also robust against the geometric distortions.

1. Introduction

With the growing applications of Internet and other multimedia systems, tremendous amount of digital products are being generated and circulated through various information systems each year. The security of these products has becoming an important technical problem which has been studied over the past few decades. A typical solution is digital watermarking, which has been applied in many information security applications, such as copyright protection, copy protection, temper detection, authentication, and broadcast monitoring [1]. Technically speaking, digital watermarking aims to hide watermark data into the actual media object without affecting its normal usage. When necessary, the owners can extract the watermark data to declare their copyright. In most of the related applications, the watermark data has to be robust against the "watermark attacks," including common image processing operations and geometric distortions [2]. For still images, the requirement of digital watermark surviving geometrical transformations is necessary since such manipulations as rotation, and scaling are common. Nevertheless, these procedures cause challenging synchronization problems for watermark detection. So, special care has to be taken so that the embedded watermark can survive geometric distortions to achieve the related functionalities in the target application. Existing image watermarking methods to resist geometric distortions can be

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classified into four types, *i.e*., Spread spectrum modulation, Invariant transform, Synchronization correction, and Feature-based algorithm [3].

Spread spectrum modulation: Spread spectrum modulation is probably the most popular approach for data hiding, which spreads the digital watermark over the host image. Based on the distribution of the coefficients in the watermark domain, different types of optimum and locally optimum decoders have been proposed. Li et al. [4] considered the problem of extracting data embedded over a wide band in a spectrum domain of a digital medium, and developed a novel multicarrier/signature iterative generalized least-squares core procedure to seek unknown data hidden in hosts via multicarrier spread-spectrum embedding. Maity and Maity [5] proposed a collusion resilient optimized spread spectrum image watermarking scheme using genetic algorithms (GA) and multiband (M-band) wavelets. Here, M-band decomposition of the host image can offer advantages of better scale-space tiling and good energy compactness, and GA can determine threshold value of the host coefficients selection for watermark casting along with the respective embedding strengths compatible to the gain of frequency response. Despite these advantages of spread spectrum modulation, the interference effect of the host image, which causes the watermark decoding performance degradation, is a major concern of the spread spectrum modulation. Besides, spread spectrum modulations are always fragile to local geometric distortions such as column removal and local affine transformation [6].

Invariant transform: The obvious way to achieve resilience against global geometric distortions is to use an invariant transform, in which the watermark can be embedded in an affine-invariant domain by using Fourier–Mellin transform, generalized Radon transform, moment invariants, histogram shape, and singular value vector respectively. Mohammad [7] presented a new digital watermarking algorithm for ownership protection, and the algorithm embeds the watermark in the Schur decomposition components of the cover image. Bhatnagar et al. [8] proposed a novel image watermarking scheme based on wavelet frame transform, singular value decomposition and automatic thresholding. The proposed scheme essentially rectifies the ambiguity problem in the SVD-based watermarking. The core idea is to randomly upscale the size of host image using reversible random extension transform followed by the embedding of logo watermark in the wavelet frame domain. Ali and Ahn [9] presented an optimal discrete wavelet transform-singular value decomposition (DWT–SVD) based image watermarking scheme using self-adaptive differential evolution (SDE) algorithm. Here, SDE adjusts the mutation factor and the crossover rate dynamically in order to balance an individual's exploration and exploitation capability for different evolving phases. Despite that they are robust against global geometric distortions, those techniques involving invariant domain suffer from implementation issues and are vulnerable to local geometric distortions.

Synchronization correction: One of the methods for detecting watermarks after geometric distortions is correcting distorted watermarked image before detecting. In [10], the 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. Ahmed et al. [11] proposed an image watermarking scheme which uses the geometric properties of an image to ensure invariance of the watermark to rotation and cropping. It also incorporates a checksum based mechanism for tracking any distortion effect in the cover work. Based on Gaussian-Hermite Moments (GHMs), Wang et al. [12] proposed a SVM correction based geometrically invariant digital watermarking algorithm, which has good visual quality and reasonable resistance toward global geometric distortions. Zhang et al. [13] derived the affine invariants from Legendre moments, and exploited the affine Legendre moment invariants for estimating the geometric distortion parameters. But, experimental results show that the synchronization correction based image watermarking schemes are also not robust against the local geometric distortions.

Feature-based: The last category is feature-based image watermarking techniques. By binding the digital watermark with the geometrically invariant image features, the watermark synchronization error can be avoided. Moreover, since the watermark is embedded in a number of local feature regions formed by feature points, such watermarking methods can resist cropping. Seo and Yoo [14] presented a content-based image watermarking method based on local regions of an image. The local regions are self-adaptive image patches that deform with geometric transformations. At each local region, the watermark is embedded after geometric normalization according to the shape of the region. However, the overlapping between local feature regions has not been resolved in this approach. Nikolaidis [15] proposed a novel technique for image watermarking aiming at robustness against geometrical attacks. The first stage relies on computing a normalized version of the original image using image moments. A radial symmetry transform is then applied to the normalized image, followed by a non-maxima suppression step. The feature points extracted this way act as centers of the area where the watermark is to be embedded. To minimize image distortion, they embed the inversely normalized watermark in the original image. Deng et al. [16] proposed a new image watermarking scheme on the basis of Seo's work [14], which is insensitive to geometric distortions as well as common image processing operations. Yuan et al. [17] proposed a local Zernike moments based watermarking scheme where the watermarked image/region can be obtained directly by inverse Zernike transform. An edge-based feature detector is proposed for local region extraction, with which, the distinct circular patch of given size can be extracted for watermark embedding and extraction. Ji et al. [18] proposed a new feature-based image watermarking scheme for improving the robustness against desynchronization attacks. First, multi-scale Gaussian filtering model is used to extract feature points in original image. The stable and non-overlapped local circular regions centered at feature points are thereafter selected by combining image segmentation and feature points refinement. Finally the watermark is embedded in the Zernike moments of the normalized circular regions.