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Robust image watermarking approach using polar harmonic transforms based geometric correction ☆

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ABSTRACT

Geometric distortions that cause displacement between embedding and detection are usually difficult for watermark to survive. It is a challenging work to design a robust image watermarking scheme against geometric distortions. In this paper, we propose a robust image watermarking approach using Polar Harmonic Transforms (PHTs) based geometric correction. The novelty of our approach is that (1) the optimal Nonsubsampled Shearlet Transform (NSST), which can provide nearly optimal approximation for 2D image function, is used to embed digital watermark, and (2) the PHTs are exploited for estimating the geometric distortions parameters in order to permit watermark extraction. Experimental results show that the proposed approach not only provides better imperceptibility and robustness against various attacks (including common image processing operations and geometric distortions), but also yields better watermark detection performance than some state-of-the-art image watermarking schemes.

1. Introduction

The success of the Internet and digital consumer devices has profoundly changed our society and daily lives by making the capture, transmission, and storage of digital data extremely easy and convenient. However, this raises a big concern in how to secure these data and preventing unauthorized use, and the issue has become problematic in many areas. Digital watermarking is a promising technology for copyright protection and content authentication, providing a means to embed a unique code as a “fingerprint” into each copy of the distributed media content [1]. Whilst digital watermarking can be applied to various multimedia contents such as image, audio, and video [2]. In the past decade, image watermarking has been widely studied as a popular and powerful technique of intellectual property rights protection in the image transmission and processing. It embeds imperceptible copyright information, termed watermark, in digital images. Ownership of the contents can be verified by detecting the embedded information.

In general, a desired image watermarking scheme must resist a wide variety of possible attacks. Usually, attacks on a image watermarking scheme can be classified as common image processing operations and geometric distortions. The common image processing operations include median filtering, noise contaminating, and JPEG compression etc. In recent years, many schemes have been demonstrated to be effective against common image processing operations [3]. However, it is still an open problem to deal with geometric distortions, which bring synchronization errors and thus disable detectors to detect watermarks preserved in distorted images. Representative geometric distortions include rotation, scaling, translation, and affine transformations etc [4].

So far, many robust image watermarking methods have been developed, which employ various techniques such as Exhaustive search, Spread spectrum modulation, Invariant transform, Feature-based algorithm, and Geometric correction [5]. Among these robust image watermarking methods, *exhaustive search* approach is the simplest method for watermark detection after geometric distortions. 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 approach is feasible for a restricted number of hypothetical deformations (e.g., scaling, rotation, and translation), but it rapidly becomes intractable as the number of possible distortions increases. Furthermore, it tends to largely increase the false positive probability [6]. *Spread spectrum modulation* can spread the watermark information over the host image. Spread spectrum embedding could be implemented by two main ways, namely additive and multiplicative spread spectrum embedding. Its robustness against common image processing operations and some

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geometric distortions, and its simple decoder structure make spread spectrum attractive for image watermarking. But, 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 random cropping [7–9]. *Invariant transform* is a simple way to achieve resilience against geometric distortions, in which the watermark can be embedded into the original host by using Fourier-Mellin transform, generalized Radon transform, singular value, polar harmonic transforms (PHT), QR decomposition, and histogram shape respectively. However, the implementation difficulties hinder the research of image watermarking schemes based on this principle. 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 lowpass filtering and lossy compression [10–12]. *Feature-based watermarking techniques* can use image content to recover the watermark after geometrical distortions. Its basic idea is that, by binding the watermark with the geometrically invariant image features, the watermark detection can be done without synchronization error. However, some drawbacks indwelled in current feature-based techniques restrict the performance of watermarking system. First, the feature point extraction is sensitive to image modification. Second, the computational complexity in calculating the features of an image before watermark detection is added. Third, the capacity of watermark data is small [4,13,14]. *Geometric correction* refers to the distortion compensation of imaging sensors, calibration, and geometric normalization, which can be used in robust image watermarking before extracting the watermark message. For geometric correction based digital image watermarking, the distorted watermarked image need to be corrected before detecting watermarks.

Based Nonsubsampled Shearlet Transform (NSST) and polar harmonic transforms (PHTs), we propose a fuzzy support vector machine (FSVM) correction based geometrically invariant image watermarking approach, which has good visual quality and reasonable resistance toward geometric distortions. The key advantages of the proposed watermarking approach lies in that: First, the optimal NSST, which can provide nearly optimal approximation for 2D image function, is used to embed digital watermark. Second, the excellent PHTs and FSVM are exploited for estimating the geometric distortions parameters in order to permit watermark extraction. The rest of this paper is organized as follows. A review of previous related work is presented in Section 2. Section 3 recalls some preliminaries about Nonsubsampled Shearlet Transform. In Section 4, the polar harmonic transforms theory is described. 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

Theoretically, geometric distortion is a mapping function that establishes a spatial correspondence between all points in an image and its warped counterpart. Thus, geometric distortion can be seen as the distortion of the image through a distorting mirror. Here, geometric distortion usually refers to powerful computer graphics tools for photo, cinema and television. These tools are always used to attack maliciously watermarked content, but with the prior goal to disturb the watermark content of the image for watermark system extractor scheme and the minimum for human vision system. Geometric correction is a distortion compensation technique of imaging sensors, calibration, and geometric normalization, which can be utilized in geometrically invariant image watermarking.

Recently, the geometric correction based robust image watermarking approaches gain more and more attention. Based on local quaternion Fourier spectral analysis (LQFSA), Ma et al. [15] introduced invariant feature transform (IFT) and geometric correction scheme in order to resist geometric distortion. Liu et al. [16] 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. Zhao et al. [17] proposed a digital watermarking scheme featuring centroid-based sectoring. To get higher robustness against geometric attacks, a delicate synchronization mechanism was developed and incorporated into the proposed approach. During the process of watermark embedding, the original image was partitioned into sectors based on the image centroid. Synchronization information as well as the message bits is then embedded into these sectors. With the help of the centroid-based sectoring and synchronization information, the proposed approach is capable of restoring the correct sectoring even if it has experienced severe geometric distortion. Zhuang et al. [18] presented a new robust watermarking algorithm which could against Geometric Attack. This algorithm first inserts the watermark into the original image, and then construct a watermarking image feature description table (IFDT) by doing a serial of image operation, which including Harris corner detection, Delaunay trigonometry network generation and Hu invariant moments computation. With the help of IFDT, we can do geometric correction upon a geometric attacked image. Finally, the watermark can be extracted from the corrected image. Zhang et al. [19] 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. In [20], 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. Jia et al. [21] proposed an anti-geometric attack SVD digital watermark algorithm based on geometric center and image mass centroid. An improved block-based SVD is employed to embed and extract watermark. Based on the invariance of geometric center and image mass centroid, the conducted geometric transform can be detected, and the attacked image is corrected before extraction according to the detected transformation parameters.

More Recently, some new geometrical corrections are introduced to the image watermarking domain. Ahmed et al. [22] 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. In approach [23], 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. Based on significant bitplane and Zernike moments theory, Yang et al. [24] proposed a robust blind image watermarking method in undecimated discrete wavelet transform (UDWT) domain, in which watermark extraction can be carried out after watermarked image has been synchronized without original host. In scheme [25], in order to obtain the rotation, scaling and translation (RST) parameters, the support vector machine (SVM) are utilized to learn image