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Geometrically invariant image watermarking based on fast Radial Harmonic Fourier Moments

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ABSTRACT

In order to reduce the time complexity and improve the reconstruction performance of traditional method for Radial Harmonic Fourier Moments (RHFMs), we introduce a fast and precise method by using FFT and based on the which, this paper proposes a novel image watermarking algorithm which is robust to geometric attacks. We firstly compute the RHFMs of the original image by using the proposed method and select the robust RHFMs which are suitable for watermark embedding. Then the watermark is embedded by modifying the magnitudes of RHFMs based on quantization. In the decoder, the watermark can be extracted from the magnitudes of RHFMs directly without using the original image. Simulation results show the proposed algorithm provides an excellent watermark invisibility and can be resilient to geometric attacks and common image processing attacks effectively.

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1. Introduction

Along with the pace of digitalization and informatization, the protection of image copyright becomes a realistic problem. As a crucial technology for image copyright protection, image watermarking technology have been extensively used and researched [1,2]. A good-performing watermarking algorithm must be robust to a variety of attacks, including geometric attacks and common image processing attacks. At present, the research on robust image watermarking mainly concentrates on resisting geometric attacks and numerous algorithms have been proposed, which can be generally classified into three categories: (1) synchronous correction algorithm. The basic principle of such algorithm is to identify the distortion parameters of the attacked image and then apply the inverse transform to the attacked image in order to extract the watermark. And such algorithm includes extensive search algorithm [3], template insertion algorithm [4] and parameter predict algorithm [5,6] which all suffer a high computation complexity and low computation efficiency. (2) Feature-based algorithm. The basic idea is to embed the watermark information into the invariant local feature regions, which are generated using the most-stable local feature points of image [7,8]. Such algorithm has an outstanding performance to resist local geometrical distortion, but with a limited local region capacity where watermark can be placed. (3) Invariant transform algorithm. Such algorithm aims at finding geometric invariance of the original image before watermark is embedded [9]. Thanks to the geometric invariance which remains unchanged after image geometric attacks, the embedded watermark information can resist geometric attacks. Generally speaking, we are interested in the watermarking algorithm based on invariant transform.

The typical invariant transforms mainly include Fourier–Mellin transform [10,11], generalized Radon transform [12,13], histogram shape [14,15], singular value vector [16,17], etc. Due to the ability of represent global features and geometric invariance, image moments have been widely used in image processing [18] and pattern recognition [19]. In recent years, numerous image watermarking techniques have been proposed by using invariant moments. In 2000, Alghoniemy et al. [20] first applied image moments to image watermarking technology by using seven Hu moment invariants. Ever since, a great deal of image watermarking algorithms based on invariant moments have been proposed. The Zernike moments were first introduced into image watermarking by Farzam and Shirani [21]. In their research, original image was firstly partitioned into a series of concentric rings and watermark was embedded into Zernike moments of these rings. Xin et al. [22] presented a robust image watermarking algorithm based on Zernike moments (ZMs) and pseudo-Zernike moments (PZMs), in which the watermark is embedded in precise and robust part of ZMs/PZMs to resist the geometric attacks. In [23], a content-based watermarking scheme that combines the invariant feature extraction with watermark embedding by using Tchebichef moments is presented by Deng et al. In this algorithm, Harris–Laplace

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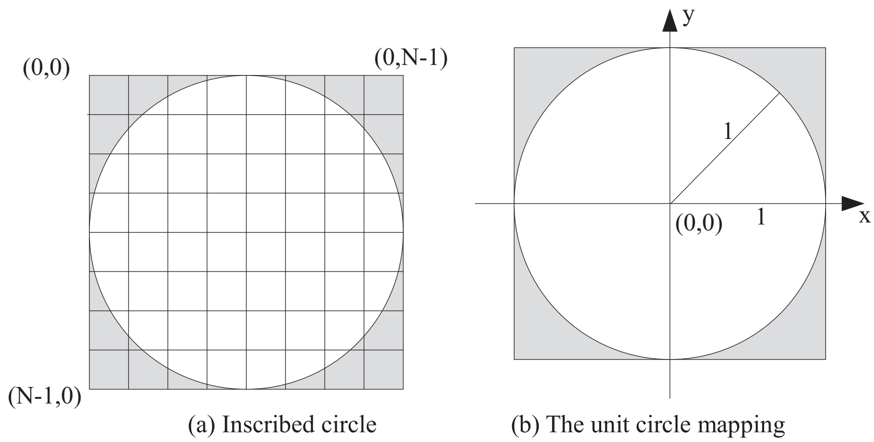

Fig. 1. Image mapping: (a) inscribed circle and (b) the unit circle mapping.

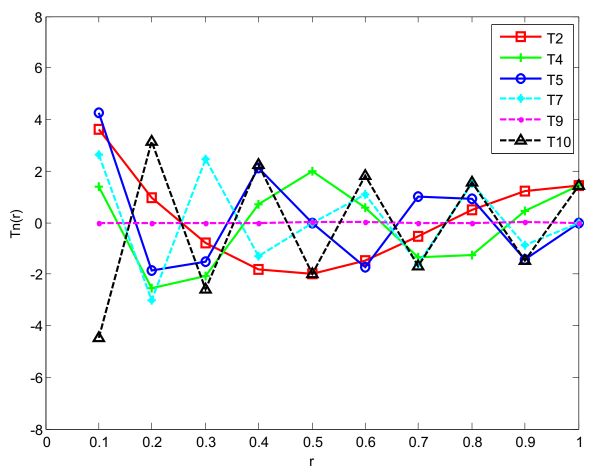

Fig. 2. $T_n(r)$ for various order n.

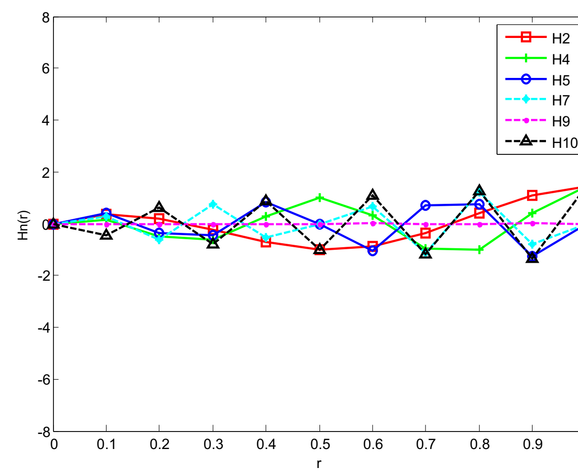

Fig. 3. $H_n(r)$ for various order n.

detector is first adopted to extract feature points, and then non-overlapped disks centered at feature points are generated. Then the watermark is embedded in magnitudes of Tchebichef moments of each disk via dither modulation to realize the robustness to common image processing operations and the blind detection. Venkataramana et al. [24] applied Krawtchouk moments to watermark insertion and detection, in which the watermark signal is embedded into the original image by modifying some of the Krawtchouk moments. In [25], Zhang et al. proposed a new algorithm which is robust to the geometric distortion by using Affine Legendre Moment Invariants and the novelty of this algorithm lies in a set of affine invariants which is derived from Legendre moments. Based on a set of orthogonal basis, Yap et al. [26] introduced the Polar Harmonic Transform (PHT) as a new orthogonal moment. Li et al. [27] came up with a geometrically invariant image watermarking using Polar Harmonic Transforms (PHTs), in which the invariant properties of PHTs are discussed and the watermark information is embedded into a set of precise PHTs.

Radial Harmonic Fourier Moments (RHFMs) were first put forward in [28]. RHFMs are free of numerical instability and offer a better depiction of the image, which make them more suitable for image watermarking and pattern recognition. Hence, we will carry out our research by using the RHFMs in this paper. Recently, some image watermarking algorithms based on the RHFMs have been proposed. Yang et al. [29] proposed a robust image watermarking scheme against local geometric distortions. This scheme has an outstanding performance to resist local geometrical distortion, but with a limited local region capacity where watermark can be placed. Niu et al. [30] introduced quaternion radial harmonic Fourier moments (QRHFMs) for color images. In this paper, the authors analyze and discuss the geometric invariant property of QRHFMs, and propose a geometric invariant color image watermarking scheme using QRHFMs. The above two algorithms do not discuss the computing method of RHFMs and analyze the relationship between reconstruction performance and the number of used RHFMs. Since the traditional computation method of RHFMs has obvious shortcomings, such as slow computing speed and poor reconstruction performance. Singh et al. [31] presented an accurate and fast computing method for radial harmonic Fourier moments. And based on this method, the authors propose an image adaptive technique for high capacity watermarking scheme. In this paper, the accuracy of RHFMs is achieved by the Gaussian quadrature technique for numerical integration of kernel functions that reduces geometric and numerical integration errors in the computation of RHFMs [32,33]. In addition the speed is accelerated by the fast recursive algorithms for the radial and angular functions of the RHFMs and their 8-way symmetry/anti-symmetry properties. Singh et al. [34] proposed a fast computation method for the polar harmonic transforms on the basis of [31]. This paper develops a fast approach for their computation using recursion and 8-way symmetry/antisymmetry property of the kernel functions. The clustering of pixels at eight radially symmetrical locations enhances the speed of computation. This method can be easily extended to the fast computation of RHFMs. Although these papers have improved the computational speed of RHFMs, the time

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