Geometrically Invariant Image Watermarking Based on Feature Extraction and Zernike Transform

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Abstract

A robust and geometric invariant digital image watermarking scheme based on feature extraction and local Zernike transform is proposed in this paper. The Adaptive Harris Detector is proposed to extract feature patches for watermarking use. A local Zernike moments-based watermarking scheme is raised, where the watermarked patches can be obtained directly by inverse Zernike Transform. Each extracted circular patch is decomposed into a collection of binary patches and Zernike transform is applied to the appointed binary patches. Magnitudes of the local Zernike moments are calculated and modified to embed the watermarks. Inverse Zernike transform is applied to reconstruct the watermarked binary patch. Experimental results show that the proposed scheme is very robust against geometric distortion such as rotation, scaling, cropping, and affine transformation, and common signal processing.

Keywords: *Geometric Invariant, Feature Extraction, Adaptive Harris Detector, Local Zernike Transform, Inverse Zernike Transform*

1. Introduction

Digital watermarking is proposed as an effective solution to the problems of multimedia copyright protection and data authentication. Quite a number of geometric invariant algorithms have been proposed in the past years [1]. Three main categories of digital image watermarking schemes can be divided: to embed the watermark in the geometric invariant domain [2-4]; to embed a template along with the watermark [2, 3]; and to embed the watermark base on feature extraction approaches which recently have been shown to have better performance in terms of robustness [4-7].

Moments and its invariant functions have also been extensively used for invariant feature extraction in a wide range of pattern recognition applications [8-10]. Of various types of moments, Zernike moments have been shown to be superior to the others in terms of their insensitivity to image noise, information content, and ability to provide faithful image representation. Therefore, they are employed for watermarking in many literatures for its special invariance properties against distortions.

A novel geometric invariant digital image watermarking scheme based on feature extraction and local Zernike moments is proposed in this paper. The Adaptive Harris Detector is proposed for more robust feature points extraction. Due to the cumulative computational errors of Zernike transform, it is difficult to reconstruct watermarked image/patch without visible quality degradation directly using its inverse transform. Therefore, the bit-plane decomposition based scheme is proposed. Each extracted

circular patch is decomposed into a collection of binary images and Zernike transform is applied to the selected binary patches.

The details of the scheme will be addressed in the following sections. Section 2 gives detail procedure of the proposed Adaptive Harris Detector. Section 3 illustrates the detail procedure of watermark embedding and extraction. Section 4 presents the experimental results to demonstrate the robustness performance of the proposed scheme. And section 4 draws the conclusions.

2. Adaptive Harris Detector

Harris Corner detector was developed for 3-D reconstruction by Harris and Stephens. It uses differential features of the image to extract salient points. In this paper, the Adaptive Harris Detector is proposed to extract feature points. The proposed algorithm is explained in detail as following. It can extract a given number of feature points with much more robustness.

Adaptive Harris Detector Algorithm

Input: *Host Image, Number of Feature Points - N, Radius of Embedding Region – r;*
Output: *N Feature Patches*

STEP-1: Load the host image and calculate its response value R_H; initialize the response threshold as *T_R* and initialize *N_FP* equals to *N*.

STEP-2: Extract the feature points with *T_R* and count the number of extracted feature points as *C*.

STEP-3: Adjust *T_R* according to *N_FP*, if *C > N_FP*, increase *T_R*; otherwise, decrease *T_R*, until *C* equal to *N_FP*.

STEP-4: Rank the extracted feature points in descending order, according to their response *R* values; remove the feature points adjacent to the one with higher rank, using the feature point with the highest rank as the criteria; and remove the feature points at edge.

STEP-5: Count the number of filtered feature points as *C_F*, if *C_F < N*, increase *N_FP* by 1 and repeat STEP-2 to STEP-4; until *C_F* equals to *N*.

3. Watermark Embedding and Extraction Procedure

The flow chart of proposed watermark embedding is shown in Figure 1. Firstly, Adaptive Harris Detector is applied to the host image to extract feature points. Each extracted patch is decomposed into *m* binary circular patches. Some of the binary patches are appointed for watermark embedding. Each appointed binary circular patch is translated to its centroid, and scaled to a standard size; afterwards, Zernike transform is applied into the normalized binary patch to calculate its Zernike moments. The magnitudes are proved to be so robust against RST attacks that they are used as watermark embedder.

The watermark is generated with a predefined seed. Spread spectrum communication technique is used to embed the watermark, as shown in equation (1).

$$Y = X + \alpha \times W.$$ **(1)**

Where *X* denotes Zernike moments magnitudes, α is the predefined parameter to control the watermark embedding strength, and *W* presents the random watermark sequence of Gaussian distribution. *Y* is the watermarked data.

After watermark being embedded, inverse Zernike transform is applied to reconstruct the corresponding binary patch from the watermarked Zernike moments. Each watermarked patches can be obtained by recomposing process with equation (2). Finally, the watermarked image can be obtained by replacing the original patches with the watermarked patches.

$$I = I_{m-1} \cdot 2^{m-1} + I_{m-2} \cdot 2^{m-2} + ... + I_1 \cdot 2^1 + I_0 \cdot 2^0. \tag{2}$$

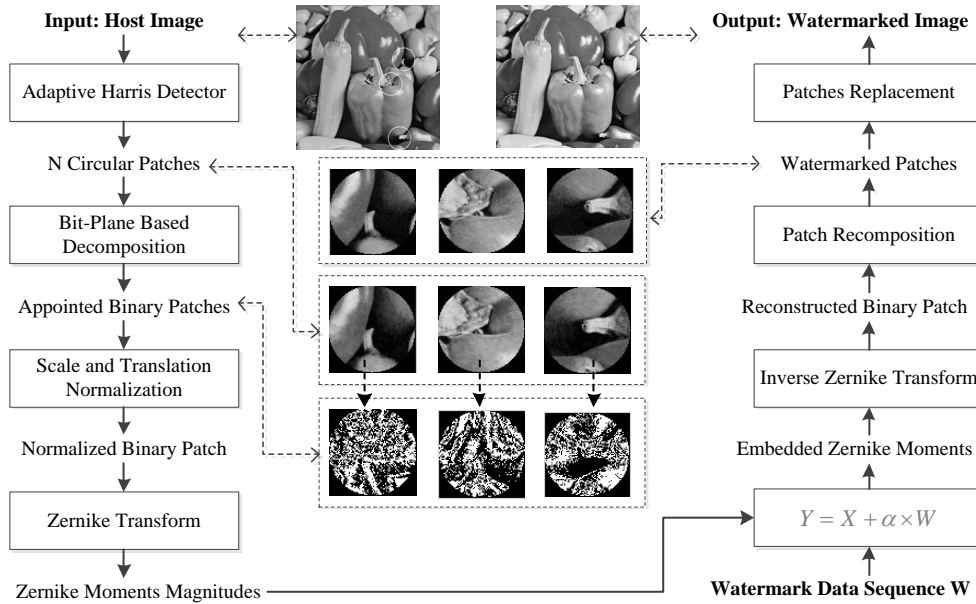Where I_i denotes the corresponding decomposed bit plane patch.

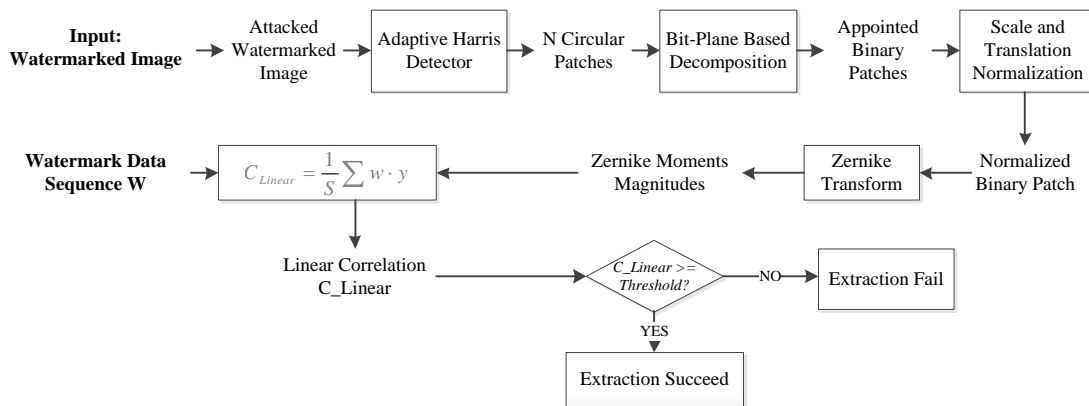**Figure 1. Flow Chart of Watermark Embedding Procedure**

Figure 2. Flow Chart of Watermark Extraction Procedure

For watermark extraction, the inverse procedure of watermark embedding is operated and the flow chart is shown in Figure 2. The linear correlation defined in equation (3) [7] is used to detect the existence of the watermark in the Zernike moments magnitudes.

The watermark is detected when the linear correlation result is larger than a predefined threshold value.

$$C_{Linear} = \frac{1}{S} \sum w \cdot y \,. \tag{3}$$

Where C is the linear correlation, S is size of the Zernike moments magnitudes for watermark detection, y is the watermarked data, and w is the watermark data sequence generated by using the same seed used in watermark embedding process.

4. Experimental Results

Many experiments are implemented to evaluate the proposed watermarking scheme on the popular test images of size 512*512. In the following experiments, the number of feature points N is set to be 3. The radius r of the extracted circular patches is set to be 40. For watermarking, each circular patch is decomposed into 8 binary patches. The order of Zernike transform is defined as 40. The watermark is generated randomly under Gaussian distribution and the watermark embedding strength α is set to be 10. PSNR (Peal Signal-to-Noise Ratio) is used to evaluate the distortion of the watermarked image. By experiments, the fifth bit plane of each selected patch is adaptable for watermarking, to ensure the success of watermark extraction and to decrease distortion of the image.

(a1) Original ′Baboon′   (b1) Original ′Bridge′   (c1) Original ′Lena′   (d1) Original ′Pepper′

(a2) Watermarked ′Baboon′ , PSNR=44.2529dB   (b2) Watermarked ′Bridge′ , PSNR=44.9124dB   (c2) Watermarked ′Lena′ , PSNR=44.6204dB   (d2) Watermarked ′Pepper′ , PSNR=43.9871dB

Figure 3. Test Images and Watermarked Images

Figure 3 shows the test images and their watermarked images; and also the PSNR between them are given. The PSNR values between the original and the watermarked images are 44.25, 44.91, 44.62, and 43.99dB for 'Baboon', 'Bridge', 'Lena', and 'Pepper', respectively. Fig. 4 shows the extracted patches from the watermarked images under various attacks. (a) The original image 'Pepper'; (b)-(k) The watermarked image attacked by: (b) JPEG compression, with the quality factor of 30; (c) 4x4 median filtering; (d) 9x9 Gaussian Low-pass filtering with its deviation as 1.5; (e) Scaling, with

the scale factor of 0.5; (f) 30° rotation with cropping; (g) 10 rows and 20 columns jitter; (h) 20% affine transformation; (i) 30% vertical shearing; (j) 30% horizontal shearing. In our scheme, as long as one patch correctly extracted, the patch extraction is successful. In Figure 4, the circular patches highlighted in red are the ones correctly extracted; it can be easily seen that at least two patches can be correctly extracted with the Adaptive Harris Detector when the watermarked image is distorted by various attacks.
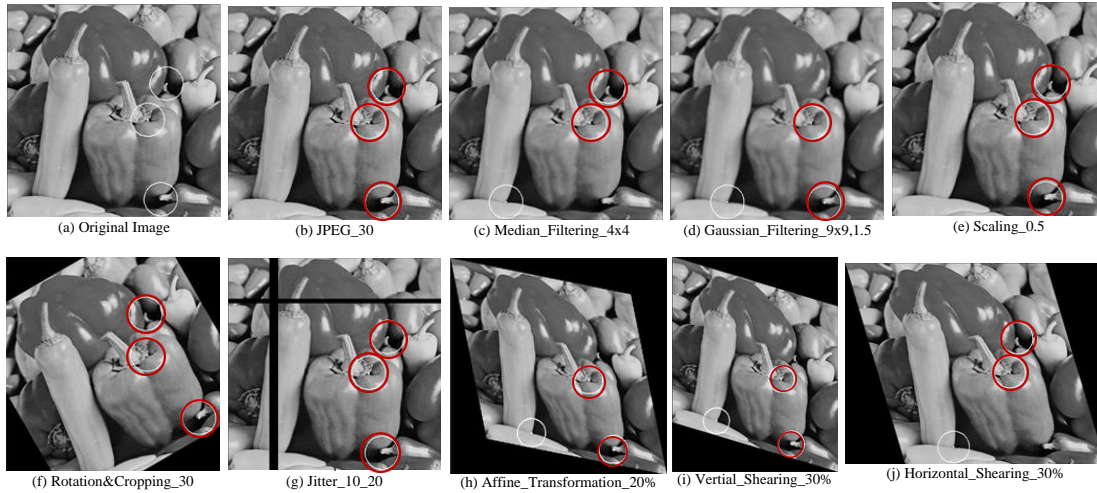

(a) Original Image (b) JPEG_30 (c) Median_Filtering_4x4 (d) Gaussian_Filtering_9x9,1.5 (e) Scaling_0.5

(f) Rotation&Cropping_30 (g) Jitter_10_20 (h) Affine_Transformation_20% (i) Vertial_Shearing_30% (j) Horizontal_Shearing_30%

Figure 4. Extracted Patches Extracted from Watermarked Images under Various Attacks

With the simulation results, the proposed scheme is compared with the existing feature-based schemes proposed by Tang and Hang [5] in 2003, and Zheng et al. [7] in 2009, under amounts of attacks. Table 1. presents the comparison results, revealing that the proposed scheme performs well compared with the existing methods.

Table 1. Experimental Results Comparison

Attacks	Methods		
	Tang and Hang [5]	Zheng et al. [7]	Proposed Scheme
Image Rotation	$1^{o} - 5^{o}$	$0^{o} - 360^{o}$	$0^{o} - 360^{o}$
Image Scaling	–	$0.7 - 1.8$	$0.4 - 3$
Image Cropping	Up to 10%	–	Up to 40%
Affine Transformation	Up to 5%	–	Up to 20%
JPEG compression	$40 - 100$	$10 - 100$	$10 - 100$
Median Filtering	3×3	–	8×8
3×3 Gaussian Filtering	Pass	$<= 0.5$	$<= 2$
Embedding Image	Gray Images	Gray Images	Gray Images

In Table 1, the dash '−' indicates that the simulation was not recorded in the literature.

5. Conclusion

In this paper, the digital image watermarking scheme based on feature extraction and using local Zernike transform is proposed. The Adaptive Harris Detector is proposed for local region extraction. Bit-plane decomposition method is used to decompose each patch into a collection of binary patches. Zernike transform is applied to each appointed binary patches to calculate Zernike moments for watermarking use.

The proposed scheme is proved to survive geometric distortions very well. It is very robust against image rotation, scaling, cropping, affine transformation and common signal processing. The comparison results show the proposed scheme outperforms the several representative feature extraction based schemes in terms of robustness to various attacks.

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